ACADEMY OF SCIENCES

UNITED PROVINCES OF AGRA AND OUDH

ALLAHABAD

BUSINESS MATTERS

1935-36

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ALLAHABAD

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PATRON

His Excellency Sir Harry Haig, K.C.S.I., C.I.E., I.C.S.
The Governor of the United Provinces of Agra and Oudh.

HONY. FELLOWS

The Hon'ble Sir J. P. Srivastava, Kt., M.Sc. (Tech.)
The Minister of Education,
The United Provinces of Agra and Oudh.

Pandit Madan Mohan Malaviya, LL.D.,
Vice-Chancellor,
Benares Hindu University, Benares

BENEFACTOR

The Vice-Chancellor,
Allahabad University, Allahabad

ANNUAL MEETING

The Annual Meeting of the Academy of Sciences was held in the Vizianagram Hall, Muir College Buildings, Allahabad, at 4-30 p.m. on Thursday, December 19, 1935. His Excellency Sir Harry Haig, K.C.S.I., C.I.E., I.C.S., Governor of the United Provinces of Agra and Oudh and Patron of the Academy, presided over the function. Dr. P. L. Srivastava, the General Secretary, read the Annual Report of the Academy of Sciences, U.P.

Prof. N. R. Dhar, the President of the Academy, read his address. His Excellency Sir Harry Haig, then, delivered his address.

The Hon'ble Sir Shah Mohammad Sulaiman, Kt., M.A., LL.D., proposed a vote of thanks to His Excellency the Patron and Prof. K. N. Bahl seconded the vote.

Secretaries' Report

PRESENTED AT THE ANNUAL MEETING OF THE ACADEMY ON DECEMBER 19, 1935

BY

DR. P. L. SRIVASTAVA.

We have the honour to submit the following report of the working of the Academy during the period beginning from the 1st of January, 1935, and ending up to date.

The Fourth Annual Meeting of the Academy of Sciences of the United Provinces of Agra and Oudh was held in the Physics Lecture Theatre, Muir College Buildings, Allahabad, at 3 P.M. on Wednesday, February 27, 1935. Dr. Sir L. L. Fermor, Kt., O.B.E., D.Sc., A.R.S.M., M. Inst. M.M., F.G.S., F.A.S.B., F.R.S., Director, Geological Survey of India, and the President of the National Institute of Sciences of India, presided over the function. His Excellency Sir Harry Haig, the Patron of the Academy, and the Hon'ble Sir Jwala Prasad Srivastava, the Minister of Education, United Provinces, sent messages for the occasion.

We are glad to record the steady progress that the Academy is making both as regards its membership and the standard of its publications. The Academy has now on its rolls 175 members, of whom 52 are non-resident members and 40 are Fellows of the National Institute of Sciences of India. The Journal of the Academy has received good recognition in India as well as outside India. The articles published have been highly appreciated and profusely quoted in scientific journals all over the world and have been abstracted in all the important Science Abstracts. We are now receiving 125 Foreign and Indian scientific journals in exchange.

The financial position of the Academy has not been quite sound. We are deeply grateful to the Government of the United Provinces of Agra and Oudh for the grant which we have been receiving for the last four years. In the first year of its existence the Academy of Sciences, U. P., received a grant of Rs. 4,000 per annum and it was in the hope that this grant would be made a recurring one that this Academy began to function. In subsequent years, however, owing to financial stringency, the Government has been giving us only Rs. 2,000 per annum. But now we hope that the Government will be pleased to sanction a recurring grant of Rs. 4,000. As for the present year we hope that this sum will be given to us from the savings. We are grateful to the Universities of Allahabad, Agra and Nagpur for the donations of Rs. 500, Rs. 250, and Rs. 100 respectively. We are also grateful to Sir Shah Mohammad Sulaiman, Kt., Chief Justice, High Court of Judicature, Allahabad, for a donation of Rs. 250 to the Academy, and to Pandit Iqbal Narain Gurtu, Vice-Chancellor, Allahabad University, for a donation of Rs. 100 this year.

We have been able to publish five issues of our Proceedings during the year 1935. Although we have increased the number of pages of the last two issues of our Proceedings, we have not been able to print all the papers read before the Academy which were found suitable for publication in the Proceedings by eminent referees.

Unfortunately any attempt to increase the number of pages in any issue of the Proceedings or the number of issues in a year has to be restricted on account of financial difficulties. Although there are many important foreign scientific societies eager to exchange our Proceedings with their publications, we are not in a position to send our Proceedings to all of them, as the finances do not permit us to do so. For these reasons again we have not yet been able to organise properly a Science Library. The need for a building of the Academy, in which we can house our library, which is rapidly increasing in size, and hold our meetings, is urgently felt. An appeal for raising money for this purpose was addressed to the universities of India, as a result of which we received the few donations mentioned above. This appeal will be repeated and will be addressed to big industrial concerns of this country and to Indian princes also, and we shall make sustained efforts to raise the funds needed for this purpose. With the help of the Government, the Indian Universities, the industries of this country, the Indian potentates and the generous public, we hope it will be possible for us to construct a suitable building for the Academy before long and to have sufficient funds at our disposal to enable us to enlarge our activities.

For reasons which will be explained by our president in his presidential address, we have formally transformed ourselves into an All-India body, and our new name would be 'The National Academy of Sciences, India.' An important change in our Rules and Regulations is an increase in the number of fellows from 30 to 150, of which 100 will be recommended by the Council during the first year.

In accordance with the policy of the Academy to foster an atmosphere of research all over the country it has been our idea all along to hold ordinary meetings of the Academy at places outside Allahabad. On November 9, 1935, a very successful meeting of the Academy was held at Lucknow. The next meeting would be held there in February, 1936. With the increase in the members of the Academy residing at other academic centres such meetings would be held at other places also.

The Education Minister's Gold Medal has been awarded to Dr. Sikhibhushan Dutt, D.Sc. (London), Chemistry Department, Allahabad University, Allahabad, his papers having been judged to be the best published on 'Chemistry and Technology' in the Journal of the Academy.

Two new fellows, *viz.*, Sir Shah Mohammad Sulaiman, Kt., Chief Justice, Allahabad High Court, and Dr. R. N. Ghosh, D.Sc., Physics Department, Allahabad University, were elected in the Fellows meeting, dated the November 30, 1935.

Dr. Narendranath Ghatak resigned the post of the Assistant Editor, and Mr. Hrishikesha Trivedi was appointed in his place.

We wish to express our thanks to the Office-bearers of the Academy and the Members of its Council and to the Assistant Editor for their ungrudging help and active cooperation.

Address of the President

PROF. N. R. DHAR, D.SC. (Lond. & Paris), F.I.C., I.E.S.,

At the Anniversary Meeting held on 19th December, 1935.

YOUR EXCELLENCY, FELLOWS AND MEMBERS OF THE ACADEMY, LADIES AND GENTLEMEN,

My very first duty as the President of the Academy of Sciences is to offer a very hearty welcome to our Patron, His Excellency Sir Harry Graham Haig, K.C.S.I., to our Fifth Annual Meeting. His Excellency's presence at our Annual Meeting transforms this gathering of scientific men into a great ceremony. We are highly indebted to His Excellency and his Government for continuing the grant of Rs. 2,000 per annum to the Academy and we hope that it would again be raised to Rs. 4,000, the amount initially granted to us.

It is well known that this Academy of Sciences was the first to be established in India with an All-India outlook with Fellows and Members residing outside the United Provinces of Agra and Oudh; but it was not made an All-India institution in the beginning, in view of the fact that the Indian Science Congress took up the task of organizing an All-India Academy. Subsequent events have shown that this sacrifice of aspirations on our part and our cooperation with the Indian Science Congress has not helped the establishment of an All-India Academy. The Indian Academy of Sciences at Bangalore established by a group of scientists, has been trying to convince others that it is the only All-India body, and has been non-cooperating with the central institution (National Institute of Sciences, India) formed under the aegis of the Indian Science Congress. As our sacrifice has brought no unity amongst the scientists in India, we have unanimously decided to form ourselves formally into an All-India institution and have accordingly changed our rules and regulations; this decision was taken by our Council as early as 1933. We shall, however, be always willing to cooperate with any other responsible body in the formation of a central institution of a really All-India nature and shall gladly relinquish our position for the cause of unity amongst scientists in India.

AN IMPORTANT PROBLEM FOR THE INDIAN SCIENTISTS.

Our first patron, His Excellency Sir William Malcolm Hailey, in his opening address to the Seventeenth Session of the Indian Science Congress in 1930 very rightly suggested that in order to have visible coordination with the public at large it is

necessary to direct at least partially the efforts of our research workers to problems of economic and utilitarian value.

India being primarily an agricultural country, no other scientific contribution could be more valuable than that of solving the problem of the "Conservation of the soil nitrogen and the fixation of atmospheric nitrogen," on which mainly do the fertility and crop yield of a soil depend. This is even more true for India since the "Royal Commission on Agriculture in India (1928)" reported that the Indian soils are mainly deficient in combined nitrogen and the manurial problem in this country is chiefly that of nitrogen deficiency.

The poverty of Indian peasants naturally restricts the use of artificial manures to make up the deficiency in their soil. An average Indian peasant, therefore, has only to depend on his farm-yard manure (cow-dung), oil cakes, green manure, etc.

We have, after a series of researches extending over several years, discovered an entirely new and at the same time economical method of "Conservation of the soil nitrogen and fixation of atmospheric nitrogen" in the soil itself by the use of molasses, the chief by-product of the sugar industry, a product which at the present moment is simply allowed to go waste and cause a great deal of nuisance to the vicinage of a sugar factory in this country. Molasses and presscake, which is also a by-product of the sugar industry and is entirely wasted at present, have been successfully utilized for reclamation of alkaline lands. These reclaiming agents appear better than gypsum or powdered sulphur used all over the world.

UTILISATION OF THE BY-PRODUCTS OF THE SUGAR INDUSTRY.

The manufacture of cane sugar is the second largest industry in India and is only next to the textile industry. Due to the tariff duties imposed in 1932, the multiplication of sugar factories in this country has been phenomenal. India requires approximately 900,000 tons of cane sugar per year and the present output is 800,000 tons. It seems, therefore, that in the near future the country will be self-sufficient regarding this important food material.

One is, however, sorry to note that India lags behind the other sugar-producing countries, notably Java, Hawaii and Queensland regarding the amount of sugar cane produced per acre of land under cultivation as is evident from the following figures:—

Country.	Sugar cane.
India	2,400 lbs. per acre
Japan	3,340 „ „
Egypt	3,378 „ „
Java	11,988 „ „
Hawaii	18,799 „ „

It seems quite clear that if India has to stand foreign competition in 1946, when the tariff wall is likely to be removed, the cultivation of sugar cane in India must improve, as there is not much scope for improvement in the extraction of cane sugar from the juice in modern sugar factories. How can the cultivation of sugar cane be improved? The Indian peasant is proverbially poor and is unable to use artificial manures imported from foreign countries.

A good deal regarding the future of the sugar industry in India depends on the proper utilization of the molasses, the chief by-product of the sugar industry. An average specimen of molasses contains 30 to 40 per cent cane sugar, 30 per cent invert sugar (glucose), 2 to 5 per cent potash, 2 per cent lime, about 0·5 per cent phosphoric acid, about 0·5 per cent combined nitrogen, and the rest water (16 to 20 per cent). At the present moment, nearly 600,000 tons of molasses are being turned out by various sugar factories in India and this large amount of molasses containing the sugar, potash, lime, phosphate, and nitrogenous compounds, which are excellent fertilizers, is practically wasted. It would appear that if all the available sugar in the molasses could be extracted, about 400,000 tons of sugar with a selling price of about 10 crores of rupees would be available for the industry.

From the industrial point of view, therefore, the utilization of molasses is a very important problem. The rapid expansion of the Indian sugar industry has increased the production of molasses to a great extent. Apart from the wastage, the final disposal of the molasses on proper sanitary lines is at present a great problem for the sugar manufacturers in this country. It is a common one for all sugar-producing countries—a problem which has not so far been successfully solved even by the scientists in great sugar-producing countries like Hawaii, Java, etc.

MANUFACTURE OF POWER ALCOHOL.

It has been suggested that molasses could be utilized for preparing power alcohol to be mixed with petrol as motor fuel. It has been established from researches carried on in France, Germany, England and other countries that under the best of conditions, not more than 23 per cent of absolutely dry alcohol could be added to petrol for efficient working. Even if by legislation, the use of power alcohol as a motor fuel to be mixed with petrol is made compulsory in India, only a small percentage of the total output of molasses could be utilized. Besides the actual preparation of anhydrous alcohol is a difficult process requiring elaborate machinery and expert labour. Thus in the United Provinces 280,000 tons of molasses are produced annually. It is estimated that 1 ton of molasses can produce 60 gallons of alcohol. The petrol consumption of the United Provinces is believed to be 7,000,000 gallons. Hence, the maximum amount of power alcohol required for admixture with petrol is about 7,000,000/5 = 1,400,000 gallons, *i.e.*, in power alcohol only 9 per cent of total molasses produced could be utilised in these Provinces.

ACETIC ACID

It has also been found possible to convert molasses into acetic acid and acetates. It is a well-known process. Unfortunately the scope of the use of acetic acid is highly limited in this country and the world production of this commodity is greater than the demand. The Industrial Chemist to the U. P. Government has shown that only 1·5 per cent of the total yield of molasses in India could be diverted in the manufacture of acetic acid. There is hardly any use of manufacturing yeast from molasses, as this material is little used in India.

POTASH FROM MOLASSES.

Recently a patent has been taken out in Calcutta by Mr. W. J. Alcock in which the molasses is burnt up and the ash containing potash is placed in the market as a manure. This is not a satisfactory process, as in its manufacture the energy-rich and useful carbohydrates and combined nitrogen present in molasses are completely destroyed. The workers at Java and Allahabad have found out that the sugars present in the molasses are the real factors in improving soil fertility. Moreover, Dr. Voelcker in his report on the "Improvement of Indian Agriculture" (1893) and the Royal Commission on Agriculture (1928) have definitely stated that the Indian soils in general do not require potash as manure and contain more potash than average English soils. Hence the market for potash, which may be obtained by burning molasses, is very restricted.

MOLASSES AS CATTLE FOOD.

Molasses has been used as food for the cattle. Seventy to eighty parts of hot molasses mixed with approximately thirty to twenty parts of dry sifted fine bagasse pith and mineral salts and proteins are added to produce a balanced cattle food in other countries. In this country even the diet of human beings is not yet standardised. Is it not futile to expect utilization of molasses as a standard cattle food?

MOLASSES AND GLYCERINE.

During the Great War, Prof. C. Neuberg of Berlin converted sugars into glycerine, which could be utilized in the manufacture of high explosives. Unfortunately in normal conditions this process is unworkable as the cost of production of glycerine from sugar is high in comparison with that obtained in the soap industry.

MOLASSES AS FUEL

In the Queensland mills as well as in several sugar-producing countries a large proportion of the molasses produced is burnt mixed with the bagasse as a fuel. But the factories in India are incapable of utilizing molasses as fuel, as special furnaces are required for such use.

When molasses is burnt with bagasse, the resulting ash has very little value as a fertilizer, owing to the potash being insoluble. It appears, therefore, that from the

economic point of view the majority of the molasses produced in sugar-producing countries should be utilized in ways other than the above.

MANURIAL PROBLEM IN INDIA.

As has already been mentioned the Royal Commission on Agriculture in India (1928) reported that the Indian soils are mainly deficient in combined nitrogen and the manurial problem in India is in the main one of nitrogen deficiency. It is a well-established fact that for the healthy growth of a plant and a proper yield of crop, nitrogen compounds or combined nitrogen must be supplied to the soil. Just as animals require nitrogen compounds for their existence, the plants should also be fed with nitrogenous materials. The uncombined nitrogen present in the air is not directly absorbed by the majority of the plants, and cannot serve as a plant food material. In European and more advanced countries of the world, ammonium salts, urea, nitrates, cyanamide, etc. are supplied to the soil as manure for the nitrogen need of plants and improving the crop yield. All these compounds form ammonium salts in the soil. The advanced nations are competing with each other in the manufacture of ammonium salts and nitric acid by the combination of the Haber-Bosch and Ostwald processes and it is no exaggeration to state that the standard of civilization of a country can be judged by the amount of nitrogen of the air fixed for the production of synthetic ammonia from the nitrogen of the air, just as in the past the amount of sulphuric acid or soap consumed formed a basis of the standard of the efficiency of a country. The addition of ammonium salts to the soil largely improves the yield of crops and under favourable conditions the yield can be doubled, *e.g.*, in Belgium the yield of wheat per acre is double that obtained in India.

In India not a single firm exists for the fixation of the nitrogen of the air and naturally ammonium salts manufactured in other countries have to be used for the soil but the Indian peasant is too poor to utilize the imported and costly ammonium salts. They utilize farm yard manure (cow-dung), oil cakes, green manure, etc. All these substances contain proteins or complex nitrogenous compounds. The proteins supplied to the soil with manure are first converted into ammonium salts, which in their turn combine with the oxygen of the air present in the soil forming nitrites. The nitrites are also oxidised (combine with the oxygen of the air) to nitrates, which are the real nitrogenous plant food material. The plants absorb nitrates from the soil and utilize them for the building of proteins or nitrogenous compounds in their bodies. Ammonium salts are very seldom and nitrites not at all, used up directly by plants.

MOLASSES AS FERTILIZER.

The experiments carried on in the Chemical Laboratories of Allahabad University show conclusively that the combined nitrogen (that is the most important substances necessary for plant growth), *e.g.*, ammonium salts and nitrates are considerably

increased when molasses, the waste product of sugar factories in India, is added to the soil and the soil well-ploughed. It has already been stated that the molasses contains a large percentage of carbohydrates. How is it that the addition of carbohydrates to the soil increases its combined nitrogen content? Just as carbohydrates on combination with the oxygen of the air supply energy to the animals, the oxidation of the carbohydrates added to the soil with molasses sets free energy, which is utilized in the combination of atmospheric nitrogen and oxygen present in the soil leading to the formation of nitrates. The production of nitrates from air requires energy and this is supplied to the soil by the oxidation of the carbohydrates added with molasses. The nitrates formed in this way on the addition of molasses to the soil, which has been well-ploughed, react with the carbohydrates with the formation of ammonium salts and traces of amino-acids and that is why an increase in the amounts of the ammonium salts is readily detected on the addition of molasses to the soil, which has been well-ploughed. The ammonium salts thus formed in the soil are exposed to light and air and form nitrates by light absorption and also by bacterial action. Thus the most important nitrogenous compound necessary for the plant growth, *i.e.*, nitrate is added to the soil, when molasses is used as manure.

Researches carried on here show that when amounts of molasses varying from 100 to 500 maunds (1 maund=40 kilograms) per acre of soil are added after mixing with water, they produce beneficial results in increasing the yield of crop in the case of rice, wheat, sugar cane, etc. Excellent results are obtained with molasses in the cultivation of rice. Thus, in our experiments, by the application of 3,000 kilograms of molasses per acre of land and digging and watering the soil once every week for two months (May and June, 1935), 14·1 maunds of *Aus* Paddy and 26·9 maunds of straw were obtained in the molassed land, while 8·5 maunds Paddy and 22·4 maunds straw were grown in the control land.

A NEW METHOD OF NITROGEN FIXATION AND CONSERVATION AND RECLAMATION OF ALKALI LANDS.

In publications from this laboratory, it has been emphasised that light plays an important rôle in many oxidation processes taking place in the soil and that chemical and not microbial agencies may be active in these reactions (*cf.* "Influence of Light on Some Biochemical Processes" by N. R. Dhar, 1935).

For a number of years, we have been investigating the photochemical, catalytic and induced oxidations of energy-rich compounds like carbohydrates, fats, proteins and amino-acids by passing air through their solutions or suspensions at the ordinary temperature. As energy is liberated in these oxidations, it is expected that nitrogen of the air is fixed and small amounts of ammonium salts are produced in these experiments.

It is well known that the bacterial oxidation of energy-rich substances leads to the formation of ammonium salts in pure cultures as well as in the leguminous plants.

It is of great interest to note that nitrogen fixation is also expected in the respiration of animals and plants, because in these processes energy is liberated in presence of a mixture of nitrogen and oxygen.

We are carrying on a systematic investigation on these different types of nitrogen fixation and in this communication some of our results are recorded.

This problem is of great importance as the Royal Commission on Agriculture in India (1928) reported that the Indian soils are mainly deficient in combined nitrogen and the manurial problem in India is in the main one of nitrogen deficiency.

As molasses, which is practically a waste product of sugar factories of India, is rich in carbohydrates, we have utilised this waste product in the fixation of atmospheric nitrogen in the soil.

NITROGEN FIXATION IN THE PHOTO-OXIDATION OF CANE-SUGAR MIXED WITH STERILIZED SOIL IN QUARTZ VESSELS.

The cane-sugar, the soil and the quartz vessels were sterilised in an autoclave for $2\frac{1}{2}$ hours at 20 lbs. pressure. In each experiment 25 c.c. of the sterile distilled water were added and the quartz vessels were exposed to sunlight. The mouths of the vessels were covered with plugs of sterile cotton wool.

Method of Analysis.—For estimating the ammoniacal nitrogen present in the soil, 50 grams of the soil which was dried in a steam oven was treated with 5 grams of pure potassium chloride and 5 grams of pure magnesium oxide and 50 c.c. of water and distilled for 6 hours on a water-bath and at the same time a rapid current of air purified by passing through a solution of ferrous sulphate and sulphuric acid was aspirated. The ammonia was absorbed in two flasks containing standard solutions of sulphuric acid.

For the estimation of nitric nitrogen, the soil from which ammonia was removed by the previous procedure, was treated with one gram of Devarda's alloy free from ammonia and nitrate and 25 c.c. of 1 per cent sodium hydroxide solution and left over night for the reduction of nitrite and nitrate to ammonia. When the reduction was complete, the ammonia set free was determined as in the first stage colorimetrically by Nessler's reagent.

The total nitrogen was estimated according to the method of Robinson, McLean and Williams (*J. Agric. Sci.*, 1929, **19,** 315) by heating 5 grams of well-dried and powdered soil with 20 c.c. conc. sulphuric acid, 5 grams fused potassium sulphate and a few crystals of copper sulphate for 4 hours. The ammonium sulphate thus formed was estimated as before. In this method the total carbon is also determined simultaneously by absorbing the sulphur dioxide produced in a standard iodine solution, the excess of which is titrated against a standard thiosulphate solution. The sum of the ammoniacal and nitric nitrogen is known as available nitrogen and the

nitrogen obtained according to the modified Kjeldahl's method is the total combined nitrogen.

The following results have been obtained:—

TABLE I.

Exposed to sunlight in February and March, 1935.

	Ammoniacal nitrogen.	Nitric nitrogen	Available nitrogen.	Total nitrogen	Total carbon
Original soil ...	0·000734%	0·0035%	0·004234%	0·0458%	0·5055%
100 gms. soil+1 gm. cane sugar+50 cc. water exposed for 145 hours in 250 c. c. quartz flask.	0·00116	0·00402	0·00518	0·0466	0·7215
100 gms. soil+2 gms. cane sugar+50 c. c. water exposed for 284 hours in 250 c. c. quartz flask.	0·00155	0·00386	0·00541	0·0486	1·2245
100 gms. soil+4 gms. cane sugar+50 c. c. water exposed for 284 hours in 250 c. c. quartz flask.	0·00175	0·00386	0·00561	0·0486	1·7010

TABLE II.

Exposed to sunlight from 30th April to 15th July, 1935; total exposure for 480 hours.

Original soil ...	0·000902%	0·00368%	0·00458%	0·0474%	0·5349%
50 gms. soil+2 gms. cane sugar+25 c. c. water in 250 c. c. quartz flask.	0·001646	0·00396	0·005606	0·04921	1·686
50 gms. soil+4 gms. cane sugar+25 c. c. water in 250 c.c. quartz flask.	0·00143	0·0035	0·00493	0·0519	3·012
50 gms. soil+1 gm. cane sugar+25 c. c. water in a quartz boiling tube.	0·001422	0·0035	0·004922	0·0509	0·871
50 gms. soil+4 gms. cane sugar+25 c. c. water in a quartz boiling tube.	0·001454	0·00364	0·005094	0·054	2·998

The foregoing results show that in all cases when cane sugar and sterile soil are exposed to light in quartz vessels, there is an appreciable increase in the total nitrogen and ammonia contents. It appears, therefore, that the energy set free in the photo-oxidation of sugars can fix atmospheric nitrogen in the soil. The researches of Palit and Dhar (*cf.* Dhar, New Conceptions in Biochemistry, 1932) show that sugars are oxidised by air when exposed to sunlight. Recently J. C. Ghosh and P. C. Rakshit (*J. Indian Chem. Soc.*, 1935, **12,** 357) have obtained similar results. Further work in the fixation of nitrogen by the photo-oxidation of energy-rich compounds is in progress.

NITROGEN FIXATION IN THE INDUCED AND CATALYTIC OXIDATION OF GLUCOSE OR CANE SUGAR.

Air aspirated through two Woulf's bottles one containing a solution of ferrous sulphate in sulphuric acid and the other concentrated sulphuric acid in order to remove the oxides of nitrogen and ammonia and to kill the bacteria, was passed through an Erlenmeyer flask containing a weighed amount of glucose or cane sugar and ferrous hydroxide obtained from 1 gram of ferrous sulphate and an equivalent amount of caustic potash. After passing air, the amount of ammonia formed was distilled off by adding alkali and heating; the distillate was absorbed in dilute sulphuric acid and the ammonium sulphate estimated colorimetrically by Nessler's reagent. Two Erlenmeyer flasks containing dilute solutions of sulphuric acid were placed next to the flask containing the inductor, the last one for the absorption of ammonia from the atmosphere of the laboratory. The following experimental results have been obtained:—

TABLE III.

Glucose taken.	Glucose oxidised.	Energy set free.	NH_3-N obtained.	Energy utilised.	Efficiency.
(*a*) 1 gm.	0·08 gm.	300 cal.	0·000332 gm.	0·512 cal.	1 : 586
(*b*) 0·5 „	0·064 „	240 „	0·000270 „	0·417 „	1 : 575
(*c*) 0·5 „ with 1 gm. sodium phosphate	0·079 „	296 „	0·000334 „	0·515 „	1 : 574
Cane sugar taken.	Cane sugar oxidised				
(*a*) 1 gm.	0·04	158	0·000245	0·378	1 : 418
(*b*) 0·5 „	0·0374	148	0·000241	0·372	1 : 398
(*c*) 0·5 „ with 1 gm. sodium phosphate.	0·0716	283	0·000462	0·713	1 : 396

The results recorded in the foregoing table show that the induced oxidation of glucose or cane sugar by passing air in the absence of bacteria leads to the formation of ammonia. Using an one per cent solution of glucose, 4 milligrams of nitrogen is fixed per gram of glucose oxidised by induction, whilst 4·68 milligrams of nitrogen are fixed per gram of mannite in its bacterial oxidation (*cf.* Waksman "Soil Microbiology," 1927, p. 569). Similar results, *i.e.*, 4 milligrams of nitrogen fixation has been observed in the induced oxidation of one gram of cane sugar as against 5·9 milligrams in the bacterial fixation (*cf.* Lohnis and Pillai, *Centrbl. Bakt.*, 1908, II, **20,** 781). It appears, therefore, that the order of nitrogen fixation caused by the induced oxidation of glucose or cane sugar is practically the same as in the bacterial fixation.

NITROGEN FIXATION IN THE OXIDATION OF CANE SUGAR MIXED WITH SOIL AND EXPOSED TO SUNLIGHT IN DISHES.

In these experiments the garden soil was mixed with pure cane sugar and exposed to sunlight in enamelled dishes covered with ordinary glass plates. For the experiments in the dark the outer surface of the glass plates was covered with a thick coating of Japan black enamel. The following results were obtained:—

TABLE IV.

		Ammoniacal Nitrogen.	Nitric nitrogen.	Total available nitrogen.	Total nitrogen.	Total carbon.
	250 gm. soil alone ...	0·00356%	0·0021%	0·00566%	0·0466%	0·5134
Exposure for 16 hours spread out from 28th August to 7th September, 1935.	250 gm. soil+20 gm. cane sugar.	0·00396	0·0021	0·00606	0·0466	4·932
	250 gm. soil+20 gm. cane sugar+10 gm. sodium phosphate.	0·00436	0·0021	0·00644	0·0466	5·202
	250 gm. soil+20 gm. cane sugar+0·5 gm. N as $(NH_4)_2SO_4$.	0·04516	0·00318	0·04834	0·1289	5·721
	250 gm. soil+20 gm. cane sugar+10 gm. sodium phosphate+0·5 gm. N as $(NH_4)_2SO_4$.	0·04668	0·00318	0·04986	0·1272	5·61
	250 gm. soil+0·5 gm. N as $(NH_4)_2SO_4$.	0·0350	0·0070	0·0420	0·1166	0·5133

		Ammoniacal Nitrogen.	Nitric nitrogen.	Total available nitrogen.	Total nitrogen.	Total carbon.
Exposure for 74 hours from 28th August to 26th September, 1935.	250 gm. soil+20 gm. cane sugar.	0·0052	0·00208	0·00728	0·0482	4·831
	250 gm. soil+20 gm. cane sugar+10 gm. sodium phosphate.	0·00538	0·00208	0·00746	0 0482	5·111
	250 gm. soil+20 gm. cane sugar+0·5 gm. N as $(NH_4)_2$ SO_4.	0·045	0·0032	0·0482	0·1198	5·627
	250 gm. soil+20 gm. cane sugar+0·5 gm. N as $(NH_4)_2$ SO_4+10 gm. Sodium phosphate.	0·040	0·0032	0·0432	0·1152	5·61
	250 gm. soil+0·5 gm. N as $(NH_4)_2$ SO_4.	0·01	0·029	0·039	0·070	0·513
Exposed for 400 hrs. spread over from 28th August to 18th November.	250 gm. soil+20 gm. cane sugar.	0·0070	0·00334	0·01034	0·0537	1·532
	250 gm. soil+20 gm. cane sugar+10 gm. sodium phosphate.	0·0075	0·00035	0·0110	0·056	1·411
	250 gm. soil+20 gm. cane sugar+0·5 N as $(NH_4)_2$ SO_4.	0·0468	0·0050	0·0518	0·1010	1 872
	250 gm. soil+20 gm. cane sugar+0·5 N as $(NH_4)_2$ SO_4+10 gm. sodium phosphate.	0·0483	0·00524	0·05354	0·1152	1·789
	250 gm. soil+0·5 N. as-ammonium sulphate.	0·010	0·0028	0·038	0·066	0·513

The above results show that when soil is mixed with cane sugar in the presence or absence of sodium phosphate and exposed to sunlight and air, the ammoniacal, nitric and total nitrogen increases due to the fixation of atmospheric nitrogen.

In presence of 0·5 gm. nitrogen added as ammonium sulphate to 250 gm. soil +20 gm. cane-sugar, there is no evidence of nitrogen fixation as the total nitrogen content is 0·101%, whilst the amount actually present should have been 0·1466% (0·1% added as ammonium sulphate and 0·0466% originally present in the soil). It is quite possible that the fixation if any, may have been compensated by the denitrification which is known to take place under aerobic conditions. Moreover, the experiments show that ammonium sulphate readily undergoes nitrification when mixed with soil and exposed in dishes to sunlight and air and cane sugar markedly retards this nitrification and also the nitrogen loss observed by exposing ammonium salts to light and air.

Our results recorded in previous papers (*Proc. Acad. Sci.*, U. P., 1934, **4,** 175; 1935, **4,** 330; **5,** 61) show that the ammoniacal nitrogen goes on increasing up to a

limiting value with the time of exposure to sunlight when the exposure is continued. After this period, further exposure to light leads to a decrease of the ammoniacal nitrogen and an increase of nitric nitrogen. But the sum of the nitric and ammoniacal nitrogen is less than that obtained before. This behaviour is due to the loss of nitrogen in the gaseous state caused by the photo-chemical, catalytic and thermal decomposition of ammonium nitric formed on the soil surface. This type of denitrification is an important soil process taking place when nitrogenous compounds are present in the soil, which is exposed to light and air. A very important conclusion can be drawn from the experiments published in the foregoing papers that the amount of ammoniacal nitrogen is always greater in the soil mixed with the energy-rich compounds and receiving sunlight than in those kept in the dark (that is, in blackened vessels).

FIXATION OF NITROGEN IN THE OXIDATION OF MOLASSES MIXED WITH SOIL.

(a) *Experiments carried on in dishes.*

As molasses contain 30—40 per cent cane-sugar and 30 per cent invert sugars, it was felt that the oxidation of this substance in the soil would be an excellent source for obtaining the energy required in nitrogen fixation.

Mixtures of molasses and unsterilised soil and small amounts of water were exposed to sunlight during the months of March to November, 1935, and the carbon, total nitrogen, ammoniacal nitrogen and nitric nitrogen were estimated from time to time. In the following tables corrections were applied for the amount of ammonia introduced with the molasses, which contained 0·001 per cent ammoniacal but no nitric nitrogen.

The following results were obtained:—

TABLE V.

Amount of molasses added per kilogram of soils.		Ammoniacal nitrogen.	Nitric nitrogen.	Available nitrogen.	Total nitrogen.	Total carbon.
	Original soil	0·000734%	0·0035%	0·004234%	0·0362%	0·4025%
Exposed for 161 hrs.	5 gm.	0·000944	0·004	0·004944	0·0360	0·4521
	10 „	0·00096	0·0038	0·00476	0·036	0·5732
	20 „	0·00106	0·0038	0·00486	0·036	0·8212
	40 „	0·00113	0·0038	0·00493	0·036	1·0640
	75 „	0·00220	0·0038	0·00600	0·038	1·5220
	100 „	0·00222	0·0038	0·00602	0·046	2·081
	150 „	0·00216	0·0038	0·00596	0·0490	3·884
	190 „	0·00210	0·0038	0·00590	0·0520	4·429
Corresponding dark.	10 „	0·00111	0·0038	0·00448	0·0362	0·5632
	20 „	0·00097	0·30076	0·00475	0·0362	0·9287
	40 „	0·00043	0·00376	0·00410	0·0362	1·2310

Amount of molasses added per kilogram by soils.		Ammo-niacal nitrogen.	Nitric nitrogen.	Available nitrogen.	Total nitrogen.	Total carbon.
Exposed for 279 hrs.	5 gm.	0·00136	0·00412	0·00548	0·036	0·459
	10 ,,	0·00148	0·00412	0·00560	0·036	0·576
	20 ,,	0·00159	0·00412	0·00571	0·036	0·823
	40 ,,	0 00184	0·00412	0·00591	0·0362	1·065
	75 ,,	0·0022	0·004	0·0062	0 0382	1·329
	100 ,,	0·002	0·00324	0·00524	0·046	1·986
	150 ,,	0·00104	0·00284	0·00388	0·0442	3·424
	190 ,,	0·00037	0·00224	0·00261	0·0521	4·021
Corresponding dark.	10 gm.	0·00074	0·00324	0·00398	0·0361	0·552
	20 ,,	0·00051	0·00310	0·00361	0·0361	0·902
	40 ,,	0·00041	0·00323	0·00323	0·0361	1·102
Exposed for 850 hrs.	5 gm.	0·00092	0·00456	0·00548	0·0381	0·412
	10 ,,	0·00096	0·00462	0·00558	0·0381	0·542
	20 ,,	0·00116	0·00462	0·00578	0·0382	0.671
	40 ,,	0 00310	0·00420	0·00720	0·0389	0·912
	75 ,,	0·00175	0·0038	0·00555	0·0391	1·213
	100 ,,	0·00146	0·00362	0·00508	0·0472	1·322
	150 ,,	0·00133	0·00304	0·00437	0·0468	2·321
	190 ,,	0·00120	0·00280	0·004	0·048	3·28
Corresponding dark.	10 gm.	0·00084	0·00320	0·00404	0·0372	0·513
	20 ,,	0·00089	0·00316	0·00405	0·0372	0·882
	40 ,,	0·00094	0·00316	0·00409	0·038	1·087
Exposed for 1450 hrs.	5 gm.	0·00093	0·00452	0·00545	0·0410	0·4125
	10 ,,	0·00098	0·00464	0·00562	0·0418	0·4424
	20 ,,	0·00118	0·00504	0·00622	0·0433	0·5516
	40 ,,	0·00155	0·00490	0·00645	0·0498	0·5827
	75 ,,	0·00185	0·00464	0·00649	0·0510	0·6619
	100 ,,	0·00162	0·00422	0·00584	0·0525	0·8629
	150 ,,	0·00144	0·00396	0·00540	0·0544	1·252
	190 ,,	0·00138	0·00324	0·00462	0·0544	2·441
Corresponding dark.	10 gm.	0·00084	0·00344	0·00428	0·0380	0·500
	20 ,,	0·00090	0·00336	0·00426	0·0380	0·815
	40 ,,	0·00096	0·00344	0·00440	0·0380	0·981

The results recorded in the foregoing table show that in all cases when molasses is added to the soil, which is properly aerated, there is an appreciable increase in its ammonia and total nitrogen contents. In these cases also like those with cane-sugar, there is greater increase of ammonia in the vessels exposed to sunlight than in those kept in the dark. The amount of ammonia formed goes on increasing up to a limiting value with increase of exposure. In all these experiments the total carbon goes on decreasing with time due to its oxidation by air.

(b) *Field experiments on the application of molasses to soil.*

In these experiments known weights of molasses were added to a definite area of the soil in the field. In some experiments the soils were dug once a week, whilst in others the soil was kept unstirred in order to investigate the influence of aeration. The following results were obtained with soils dug once a week:—

TABLE VI.

	Ammoniacal nitrogen	Nitric nitrogen	Available nitrogen	Total nitrogen	Total carbon	Date of analysis
3600 kilograms of molasses added per acre of land on 30-7-35						
Original soil ...	0·00374%	0·00334%	0·00708%	0·0466%	0·542%	30-7-35
	0·00618	0·0032	0·00938	0·0467	0·673	24-8-35
	0·0067	0·0035	0·01020	0·0467	0·651	3-9-35
	0·00554	0·00445	0·00999	0·0467	0·653	21-9-35
	0·00590	0·00500	0·01090	0·0485	0·543	14-10-35
	0·00468	0·00608	0·01076	0·0482	0·543	6-11-35
7200 kilograms of molasses added per acre of land on 30-7-35						
Original soil ...	0·00350	0·00280	0·00630	0·0462	0·515	30-1-35
	0·00508	0·00262	0·00770	0·0467	0·720	24-8-35
	0·00724	0·00282	0·00906	0·0467	0·714	3-9-35
	0·00768	0·00382	0·01150	0·0467	0·711	21-9-35
	0·00734	0·00400	0·01134	0·0492	0·543	14-10-35
	0·005	0·00668	0·01168	0·0518	0·543	6-11-35
10800 kilograms of molasses added per acre of land on 5-8-35						
Original soil ...	0·00560	0·00372	0·00932	0·0522	0·581	5-8-35
	0·00612	0·00344	0·00956	0·0579	1·366	24-8-35
	0·00776	0·0037	0·01146	0·0582	1·238	3-9-35
	0.01094	0·00358	0·01452	0·0583	1·131	21-9-35
	0·01028	0·00362	0·01390	0·0588	1·086	14-10-35
	0·00822	0·00576	0·01398	0·0611	0·985	6-11-35

In these field experiments, there is also definite evidence of nitrogen fixation in the soil on the addition of molasses, as there is an increase in the available and total nitrogen.

(c) *Molasses added to soil in heaps—composts with molasses.*

A heap of soil weighing 167 kilograms was mixed with 12 kilograms of molasses (A) and another heap weighing 174 kilograms was treated with 6 kilograms of molasses (B) and exposed to air and light. For better aeration, the heaps were stirred frequently after addition of water. The molasses was added on 18th Febru-

ary, 1935, and exposed to sun till the end of June and then removed to a verandah of the laboratory before the rains set in. The following results were obtained:—

TABLE VII.

	Ammo-niacal nitrogen.	Nitric nitrogen.	Total available nitrogen.	Total nitrogen.	Total nitrogen.
Original soil ...	0·00865%	0·00582%	0·01447%	0·0458%	0·5055%
Heap (A) analysed on 18-3-35	0·01646	0·00594	0·0224	0·0538	1·0922
Heap (B) " " "	0·00934	0·00594	0·01528	0·0504	1·238
Heap (A) " " 18-4-35	0·014	0·0058	0·0198	0·0540	...
Heap (B) " " "	0·0116	0·0058	0·0174	0·0512	...
Heap (A) " " 20-9-35	0·0175	0·00822	0·02572	0·09005	1·0514
Heap (B) " " "	0·0140	0·00736	0·02136	0·09	1·035

The above results show that when molasses is added to soil in heaps and exposed to air and light, the available and total nitrogen are considerably increased. The total nitrogen is double that of the original amount present in the soil before the addition of molasses. Hence considerable fixation of nitrogen takes place and excellent composts are prepared with molassed soils, of which the carbon-nitrogen ratio becomes normal and attains the value of 11·5.

RESIDUAL EFFECT OF MOLASSES ADDED TO FIELDS.

The folowing results show that molasses when added to the soil in fields produces a residual effect:—

TABLE VIII.

	PLOT A. 1800 kilograms molasses per acre added on 25-9-34 and then wheat grown. Molassed again at the rate of 3600 kilograms per acre on 30-4-35 and analysed on 6-5-35.	PLOT B. Originally unmolassed but wheat grown. Molassed at the rate of 3600 kilograms per acre on 30-4-35 and analysed on 6-5-35.	PLOT C. Control, un-molassed but wheat grown ; analysed on 6-5-35.
Ammoniacal nitrogen	0·006%	0·0058%	0·0051%
Nitric nitrogen ...	0·0037%	0·0032%	0·0029%
Total nitrogen ...	0·0321%	0·0272%	0·0224%
Total carbon ...	0·5428%	0·5321%	0·2621%

The foregoing results show that plot A, which has been molassed twice contains more available and total nitrogen than plot B which has been molassed once and plot C, which has not been molassed at all.

LACK OF CORRELATION BETWEEN THE AZOTOBACTER NUMBER AND THE NITROGEN FIXATION IN THE SOIL ON ADDITION OF MOLASSES.

In order to investigate whether there is a proportionality between the increase of ammoniacal and total nitrogen and the Azotobacter counts in the soil, a systematic work has been carried on by Dhar and Seshacharyulu on applying different amounts of molasses to a definite area of the garden and determining the Azotobacter counts, ammoniacal, nitric and total nitrogen once every week.

The following results regarding ammoniacal nitrogen and Azotobacter counts have been obtained:—

0		90 mds. of molasses per acre.		270 mds. of molasses per acre.		Date.
Azotobacter	Ammoniacal nitrogen.	Azotobacter.	Ammoniacal nitrogen.	Azotobacter.	Ammoniacal nitrogen	
23,00000	...	51,00000	...	64,00000	...	22-10-35
24,00000	0·00124%	52,00000	0·00155%	66,00000	0·00221	26-10-35
24,00000	...	88,00000	...	68,00000	...	30-10-35
20,00000	0·0013	179,00000	0·0024	48,00000	0·00247	3-11-35
23,00000	...	167,00000	...	72,00000	...	7-11-35
27,00000	0·00122	177,00000	0·00285	577,00000	0·0026	11-11-35
23,00000	0·00121	164,00000	0·00290	5830,000000	0·00273	15-11-35
25,00000	0·00121	168,00000	0·00341	5960,000000	0·00280	22-11-35
23,00000	0·0012I	172,00000	0·00287	5040,000000	0·00290	30-11-35

It is well known that quantitative work on nitrogen fixation in pure cultures of Azotobacter fed with mannitol is carried on by estimating the ammonia formation from time to time. Hence we have also determined the increase of ammoniacal nitrogen in soil samples along with the Azotobacter counts. The foregoing results show that there is hardly any correlation between the increase of ammoniacal nitrogen and the Azotobacter numbers. If the bacterial theory of nitrogen fixation were correct, it is expected that such a coordination should exist. Hence it appears that besides bacteria, other agencies may be effective in nitrogen fixation in tropical soils.

The foregoing results in Tables V and VI obtained with molasses, when mixed with soil, show that there is an appreciable increase in the total nitrogen and ammonia contents; the amount of ammonia goes on increasing up to a limiting value when it decreases. But at this stage the nitrate content increases appreciably due to the oxidation of ammonium salts formed by nitrogen fixation. When the amounts of molasses added to the soil are not large, the maximum amount of ammonia to be formed due to the nitrogen fixation in the soil is reached within two months. After this stage the nitrate increases due to the oxidation of the ammonium salts produced from the

nitrogen fixation in the soil and there is loss of the total available nitrogen and the carbon-nitrogen ratio approaches the 11:1 value. Hence, it is concluded that at the stage when the nitrate content of the soil begins to increase appreciably, the soil is most suitable for the sowing of crops. When larger quantities of molasses are added to the soil in the fields, more time is required to attain the stage of nitrate increase. For example, from the results recorded in Table VI it will be seen that in the plot in which 270 maunds of molasses per acre were added, the largest amount of ammonia was fixed but the time required in reaching the maximum was about 3 months. Similarly, in the experiments with molasses and soil kept in dishes, the maximum increase of ammonia is attained after a longer exposure to sunlight in those dishes containing larger amounts of molasses than those with smaller amounts. Thus with 10 grams of molasses when added to a kilogram of soil, the maximum amount of ammonia formation is reached after 279 hours of exposure to sun light spread over 75 days whilst with 40 grams, the maximum is reached after 850 hours of exposure spread over 4 months. It is clear, therefore, that if the cultivator can afford to wait and can use large amounts of molasses better results are expected than with smaller amounts. Using 270 maunds of molasses per acre of land and if digging or turning over of the soil is continued for about 3 months, once in 10 days excellent results are expected. With smaller amounts varying from 90 to 180 maunds of molasses per acre, an interval of 8 to 12 weeks with occasional digging ought to be sufficient, because the maximum ammonia formation in these cases is within the above interval. It is known that the amount of nitrogen fixation in a bacterial culture of Azotobacter is quantitatively measured by the ammonia formed. Hence the evidence of nitrogen fixation in our experiments when molasses or cane-sugar is added to the soil is quite definite because there is not only considerable increase of ammoniacal nitrogen but simultaneously the total nitrogen is also increased. Moreover in a recent communication, we have shown that in soils, the available nitrogen increases with the increase of total nitrogen.

Our experimental results show that when the soil is not properly aerated after the addition of molasses, the acidity increases and the nitrogen fixation is less.

Many people have tried to use molasses in increasing soil fertility but uniformly good results could not be obtained as will be evident from the following lines:—

"Increased yields of sugarcane have followed the application of molasses to soils at the Station Agronomique and on Mr. Ebbel's estate in Mauritius, where the residual effect is well shown, and also in Antigua. Peck in Hawaii, on the other hand, observed marked losses of nitrate, as also did Harrison in British Guiana."

"Laboratory investigations in humid climates suffer from the difficulty that the soils already contain so much nitrogen that small changes are difficult to measure accurately, and there are losses of nitrogen which counter-balance any fixation. Investigation would be easier in some of the soils very poor in nitrogen found in hot, arid conditions. Rigid incontestable proof could be furnished only by a

demonstrated gain in nitrogen effected by Azotobacter, all other possibilities being ruled out. This proof has not yet been forthcoming." (Russell. "Soil Conditions and Plant Growth," 1932, pp. 342—44).

"In view of the fact that the energy added to the soil is not directly available to the nitrogen-fixing bacteria and that small amounts of available nitrogen are always present in the soil, and the error in the laboratory determination of total nitrogen by the Kjeldahl method is greater than the possible amount of nitrogen fixed by nonsymbiotic bacteria, we are still unable to decide the question definitely." (Waksman, "Soil Microbiology," 1927, p. 587).

"Wide use is being made in systems of agriculture of the bacteria, which work with legumes, but the nitrogen fixing power of those which work outside the plant is as yet not utilised extensively by man, since the methods of controlling them are not well understood" (Miller, "The Soil and its Management," 1924, p. 203). A. Koch, J. Litzendorff, F. Krull and A. Alves (*J. Landw*, 1907, **55,** 355) have reported nitrogen fixation in plates and pots with dextrose but Pfeiffer and Blanck (*Landw. Versuchs. Stat.*, 1912, **78,** 375) could not obtain any nitrogen fixation with sugar. According to Hutchinson (*J. Agric. Sci.*, 1918, **9,** 92) sugars show beneficial results in autumn but not in spring.

Dr. H. W. Kerr has reported the following yield of sugarcane on applying 10 tons of molasses per acre in the Bundaberg farm in Queensland.

No molasses	22·7 tons per acre.
10 tons molasses	37·1 " "

On the other hand, Crabtree working in the Fairy Mead farm in Queensland did not find any beneficial effect with molasses. In the discussion, Dr. Kerr stated:—"The value of the molasses is probably due to its physical, chemical and biological influences in the soil." (Proc. Second Annual Conference of Queensland Society of Sugarcane Technologists, 1932). On applying molasses to the growing crop, no beneficial effect was obtained at Pusa. Recently, an increase of yield to the extent of 36 per cent has been reported at the Shahjahanpur Government Farm on applying 270 maunds of molasses per acre in cultivation of sugarcane, before planting. Messrs. Parry & Co., Ltd., of Madras have also obtained an increase of 40 per cent in the yield of sugarcane. But when molasses was added to the growing crop, no beneficial result was obtained. It will thus be evident from the foregoing observations that up till now the conditions for obtaining uniformly good results from molasses as a manure and the mechanism of the process have not been worked out. In this as well as in previous publications (Dhar and Mukerji, *Proc. Acad. Sci.*, U. P., 1934, **4,** 175; 1935, **4,** 330, **5,** 61), we have established that the oxidation of the carbohydrates present in molasses either through the agency of bacteria or sunlight or induction and any intermediate products to carbon dioxide and water liberates energy in the soil and

this energy is utilised in the fixation of atmospheric nitrogen and that is why the ammonia and the total nitrogen contents increase and thus beneficial results in the growth of crops are obtained with molasses as fertilizer. Moreover, as molasses contain lime, potash and phosphates, its fertilising value is also increased by the presence of these substances, which are excellent food material for the plants. It is interesting to note here that previous workers determined only the total nitrogen of the soil after the addition of energy-rich compounds, and as the difference in total nitrogen is not very high before and after the addition of energy-rich compounds to the soil, they were doubtful regarding the fixation of nitrogen in the soil by the addition of energy-rich compounds. But as we have estimated, both the available (ammoniacal and nitric nitrogen) and the total nitrogen, we have been able to detect the increase of available nitrogen and also total nitrogen in all cases when energy-rich organic compounds are added to well aerated soils.

It has already been stated that many workers have failed to obtain beneficial results with molasses. Our experiments show that the failure is due to insufficiency of oxidation of the carbohydrates caused by the lack of the aeration of the soil. When the aeration of the soil is insufficient, the increase of ammonia is less and the soil becomes acidic. The amount of fixation of nitrogen depends on the energy available from the oxidation of the carbohydrates of molasses and the by-products formed from the partial oxidation of carbohydrates and that is why sufficient oxygen is necessary for obtaining beneficial results, and this is achieved if the soil is dug or turned over once a week or 10 days during the period of eight to twelve weeks between the application of molasses to the field and the sowing of crop.

AZOTOBACTER FIXES NITROGEN VERY WELL IN TROPICAL SOILS.

In cold countries, the soil temperature being low and due to lack of sunshine, the velocity of the oxidation of energy-rich substances present in the molasses may be small and thus the energy available from the oxidation of carbohydrates may be too small for any marked nitrogen fixation. That is why, many workers like Pfeiffer and Blanck, Hutchinson and others were unable to find beneficial effect with sugars. Moreover, in temperate climates, Azotobacter is not suitable for nitrogen fixation as the fixation at 10° and at lower temperature is practically nothing. The soil temperature in colder countries being lower than 10° most of the time in the year, practically no nitrogen fixation by Azotobacter is possible and that is why Azotobacter has not been utilised by agriculturists in cold countries. Thiele (*Landw. Versuchs-Stat.*, 1905, **63,** 161) measured the soil temperatures of arable and grass lands daily for three years at Breslau, Germany and reported that only rarely were they favourable for Azotobacter. Also Azotobacter requires more heat than Bacillus radicicola and several other bacteria and is eminently suitable for nitrogen fixation in tropical countries

except in the months of May and June when the soil temperature during the daytime exceeds 50°, beyond which Azotobacter is unable to fix nitrogen. This bacteria should be widely used in the fixation of nitrogen in tropical countries when fed with energy-rich substances like molasses and presscakes, etc. Recently Dhar and Tandon have measured the fixation of atmospheric nitrogen by pure cultures of Azotobacter thriving on mannite medium at 10°, 20°, 30°, 35°, 40°, 50°, 60° and 70°. It has been observed that the maximum nitrogen fixation (largest amount of ammonium salt formation) takes place at 35°, which is, therefore, the optimum temperature for tropical Azotobacter as against 28° obtained in temperate countries. There is hardly any ammonia formation at 10° on the one hand and at 60° on the other. At 70° no nitrogen fixation by Azotobacter takes place. This is a very interesting case where the lower limit of bacterial activity is much higher than with the nitrite formers, Bacillus radicicola and several other bacteria. Moreover, the upper limit for Azotobacter is also appreciably higher. For example, even at 50° Azotobacter can fix an appreciable amount of nitrogen and the fixation at 50° is almost the same as at 20°. In the case of nitrite-formers, the bacterial activity ceases completely at 50°; even at 40°, the activity of the nitrite formers is quite small in comparison to that at the optimum at 35°. These results show definitely that Azotobacter can stand high temperatures better than that of the nitrite formers and several other bacteria.

The optimum temperature for the nodule bacteria in temperate climates lies between 18° and 26° and is appreciably lower than that of Azotobacter. Moreover, Bacillus radicicola can thrive even at a temperature of 3° and that is why this bacteria has been utilized to a much greater extent in Europe and America than Azotobacter.

Russell states:—" In neutral soils of cool countries Bacillus radicicola is the most active fixer of nitrogen and Azotobacter is relatively inactive . . . . . .

In alkaline soils of warm climates, on the other hand, Azotobacter is greatly stimulated; Bacillus radicicola is not. . . ."

In tropical countries, however, if the soil is well ploughed after the addition of molasses, there is no reason why soil fertility regarding combined nitrogen should not be increased. We have applied molasses to more than 30 plots of land in different portions of the University compound and we have always observed marked increase in the ammonia and total nitrogen content of the soils on the application of molasses. In most of our field experiments the amount of ammonia after the addition of molasses and aeration has become three times the amount originally present in the soil. This is equivalent to the addition of 80 to 160 kilograms of ammonium sulphate per acre.

MOLASSES IN THE CONSERVATION OF SOIL NITROGEN.

Apart from the fixation of nitrogen molasses acts as a protector of soil nitrogen and hence it is more effective as a soil fertilizer than ammonium sulphate alone,

specially in tropical countries. Our experiments recorded in Tables XI to XIII show that the loss of nitrogen from the soil on adding ammonium sulphate is greatly decreased when along with ammonium sulphate molasses is added. We have shown that when ammonium sulphate is added to soil in shallow enamelled dishes and exposed to sunlight in the months of May, June, and July at Allahabad, as much as 60 per cent of the ammonium salt is lost. This loss can be minimised by adding molasses along with ammonium sulphate. It appears, therefore, that the value of ammonium sulphate or urea as a manure to be used in tropical countries is likely to be greatly enhanced if it is mixed with molasses or any other carbonaceous material. From the foregoing lines, it will be clear why farmyard manure or green manure produces better results in crop yields than ammonium sulphate, because the carbonaceous substances present in the farmyard or green manure, markedly retard the velocity of the oxidation of the nitrogenous compounds present in the farmyard and green manures and inhibit the processes of ammonification and nitrification and act as an agent in the conservation of the nitrogen added. Oil cakes containing fats and nitrogenous substances ought to be effective as a nitrogenous manure in tropical countries, because fats are known to retard the oxidation of nitrogenous compounds.

Russell (*Soil Conditions and Plant Growth*, 1932, pp. 76—78, and 313, 361) has reported that the yield of barley and straw with farmyard manure in the Rothamsted field experiments from 1852—1922 is better than that obtained with complete artificial manures containing ammonium salts, potassium salts and phosphates. This is due to the fact that there is more nitrogen in the field manured with cow-dung than with artificials as is evident from the following data from the Rothamsted fields:—

TABLE IX.

	Total N. per·cent.
(1) Receiving no manure since 1843 ..	0·095
(2) Receiving farmyard manure since 1852 ..	0·256
(3) Receiving complete artificials $(NH_4)_2SO_4$	0·099
(4) Receiving complete farmyard manure ..	0·253
(5) Receiving potash and phosphate but no nitrogen	0·090

TABLE X.

Total Nitrogen Balance-sheet (1865—1914) in the top nine inches of soil.

	Farmyard manure.	No. manure.	Complete Plot 7.	Artificials Plot 13.
Total N. in soil in 1865, lb. per acre.	4850	2960	3390	3320
Total N. in soil in 1865, per cent.	0·196	0·114	0·123	0·121
Total N. in soil in 1914, lb. per acre.	5590	2570	3210	3240
Total N. in soil in 1914, per cent.	0·236	0·092	0·120	0·122
Total change in 49 yrs., lb. per acre.	+740	−390	−180	−80

In order to investigate the retarding influence of molasses on the loss of nitrogen from the soils, the following field experiments were performed. 270 gms., 540 gms. and 1080 gms. of ammonium sulphate dissolved in water were applied to three plots on 26th September, 1935, the area of each plot being 144 sq. ft. To three other plots, the same amounts of ammonium sulphate were added along with 12 kilograms of molasses (*i.e.*, at the rate of 3600 kilograms per acre). All these plots were ploughed before the application of ammonium sulphate and dug once in 10 days afterwards. From time to time, the ammoniacal, nitric, total nitrogen and total carbon were estimated. The following results were obtained:—

TABLE XI.

Experiments with 270 gms. of $(NH_4)_2SO_4$ per 144 sq. ft. of land.

Condition.	NH_3-N.	NO_3-N.	Available nitrogen.	Total nitrogen.	Total carbon.	Date of analysis.
Unmolassed	0·00832%	0·0035%	0·01182%	0·0583%	0·416%	27-9-35
Molassed	0·00814	0·0035	0·01164	0·0588	0·587	"
Unmolassed	0·00636	0·00556	0·01192	0·0583	0·416	12-10-35
Molassed	0·00778	0·00426	0·01204	0·0609	0·578	"
Unmolassed	0·00608	0·00600	0·01208	0·0538	0·416	24-10-35
Molassed	0·00778	0·00582	0·01360	0·0625	0·501	"
Unmolassed	0·00438	0·00714	0·01152	0·0538	0·411	7-11-35
Molassed	0·00700	0·00636	0·01336	0·0636	0·498	"

TABLE XII.

Experiments with 540 gms. $(NH_4)_2SO_4$ per 144 sq. ft. of land.

Condition.	NH_3—N	NO_3—N	Available nitrogen.	Total nitrogen.	Total carbon.	Date of analysis.
Unmolassed	0·01206	0·00344	0·01550	0·0603	0·417	27-9-35
Molassed	0·01228	0·00344	0·01572	0·0608	0·587	,,
Unmolassed	0·00768	0·00636	0·01404	0·0609	0·416	12-10-35
Molassed	0·01076	0·00436	0·01512	0·0636	0·573	,,
Unmolassed	0·00754	0·00636	0·01390	0·0593	0·421	24-10-35
Molassed	0·01000	0·00636	0·01636	0·0673	0·507	,,
Unmolassed	0·00538	0·00776	0·01314	0·0583	0·418	7-11-35
Molassed	0·00896	0·00874	0·01770	0·0667	0·502	,,

TABLE XIII.

Experiments with 1080 gms. of $(NH_4)_2SO_4$ per 144 sq. ft. of land.

Unmolassed	0·02032	0·00356	0·02388	0·0757	0·416	27-9-35
Molassed	0·02044	0·00384	0·02428	0·0757	0·585	,,
Unmolassed	0·00874	0·00932	0·01806	0·0700	0·416	12-10-35
Molassed	0·0140	0·00636	0·02036	0·0760	0·585	,,
Unmolassed	0·00754	0·01040	0·01794	0·0636	0·416	24-10-35
Molassed	0·01272	0·00874	0·02146	0·0823	0·585	,
Unmolassed	0·00636	0·01166	0·01802	0·0612	0·422	7-11-35
Molassed	0·01000	0·00972	0·01972	0·0828	0·552	,,

The foregoing results show very well that the total and available nitrogen of the molassed plots are always greater than those in the unmolassed plots. Hence molasses act as a nitrogen sparer in the soil and this is a very important application of molasses. Moreover, there is appreciable nitrogen fixation in the soil when molasses is added to it even in presence of ammonium sulphate, as the total nitrogen in the end is always greater than in the beginning.

The following experiments showing the retarding influence of cane sugar on nitrification and nitrogen loss from soils containing ammonium sulphate were carried on in open enamelled dishes:—

Original soil contained 0·00356% ammoniacal nitrogen, 0·0021% nitric nitrogen, 0·0466% total nitrogen and 0·5134% carbon.

	TIME OF EXPOSURE.			
		62 hours.	132 hours	200 hours.
1. 200 gms. soil +16 gms cane sugar	NH_3-N NO_3-N Total—N Total—C	0·005% 0·0028 0·050 4·221	0·0070% 0·0028 0·0498 3·187	0·0084 0·0029 0·0499 1·882
2. 200 gms. soil +16 gms. cane sugar +8 gms. sodium phosphate.	NH_3-N NO_3-N Total—N Total—C	0·00582 0·0028 0·0484 4·00	0·00728 0·0028 0·0498 3·178	0·0089 0·0029 0·0499 1·761
3. 200 gms. soil +16 gms. cane sugar +0·4 gm. N as ammonium sulphate.	NH_3-N NO_3-N Total—N Total—C	0·0875 0·0028 0·1842 4·114	0·0668 0·0028 1·750 2·991	0·0624 0·0030 0·148 1·892
4. 200 gms. soil +16 gms. cane sugar +0·4 gm. N as ammonium sulphate + 8 gms. sodium phosphate	NH_3-N NO_3-N Total—N Total—C	0·0882 0·0028 0·200 4·128	0·0642 0·0028 0·178 2·991	0·0604 0·0030 0·152 1·88
5. 200 gms. soil +16 gms. cane sugar +0·2 gm. N as ammonium sulphate.	NH_3-N NO_3-N Total—N Total—C	0·028 0·0028 0·116 4·112	0·0170 0·0028 0·1112 3·019	0·0156 0·0029 0·1167 1·885
6. 200 gms. soil +16 gms. cane sugar +0·2 gm N as ammonium sulphate + 8 gms. sodium phosphate.	NH_3-N NO_3-N Total—N Total—C	0·0291 0·0028 0·1169 4·121	0·014 0·0028 0·1181 3·029	0·015 0·0029 0·1172 1·721
7. 200 gms. soil +16 gms. cane sugar +0·1 gm. N as ammonium sulphate.	NH_3-N NO_3-N Total—N Total—C	0·010 0·0028 0·0933 3·914	0·00934 0·0028 0·0934 2·871	0·00932 0·0029 0·0934 1·895
8. 200 gms. soil +16 gms. cane sugar +0·1 gm. N as ammonium sulphate + 8 gms. sodium phosphate	NH_3-N NO_3-N Total—N Total—C	0·010 0·0028 0·933 3·992	0·00922 0·0028 0·0957 2·881	0·00910 0·0029 0·0944 1·778

	TIME OF EXPOSURE		
	62 hours	132 hours	200 hours
9. 200 gms. soil + 0·4 gm. N as ammonium sulphate.	NH_3–N=0·04516 NO_3–N=0·00362 Total–N=0·1346 Total–C=0·5068	0·0233 0·00388 0·123 0·5068	0·02024 0·00422 0·0928 0·506
10. 200 gms. soil+0·2 gm. N as ammonium sulphate.	NH_3–N=0·0232 NO_3–N=0·00278 Total–N=0·1072 Total–C=0·5068	0·014 0·005 0·1060 0·5068	0·01336 0·00516 0·0875 0·5068
11. 200 gms. soil+0·1 gm. N as ammonium sulphate.	NH_3–N=0·00822 NO_3–N=0·00406 Total–N=0·0778 Total–C=0·5068	0·0082 0·005 0·0772 0·5068	0·0082 0·005 0·07 0·5068

The foregoing results show that the total nitrogen in vessels containing cane sugar and ammonium sulphate is always greater than in the corresponding ones containing ammonium sulphate alone. Thus cane sugar acts as a sparer of the soil nitrogen. It has generally been believed that organic substances like sugar when added to soil causes denitrification but in none of our experiments we observed any denitrification of this type.

According to Lyon and Wilson (*Cornell University Agricultural Experiment Station Memoir*, 1928, 115), nitrogen balance is not maintained but loss of nitrogen takes place when the crops grown during autumn only are ploughed in, followed by a summer fallow; on the other hand, gain of nitrogen is observed in the soil under grass and not disturbed for summer fallow.

Not only nitrogen fixation takes place in soil on the addition of molasses and proper aeration as revealed in our experiments, the observations of Howard and Wad (Waste Products of Agriculture, 1931, page 100) show that a certain amount of nitrogen fixation also takes place in the composting of the waste-products of agriculture according to the Indore method of composting, when the aeration in the compost heaps is sufficient. It appears, that in the oxidation of the carbonaceous substances in the compost heaps energy is liberated as is evident from the heat produced in these heaps and a part of this energy of oxidation is utilised in the fixation of nitrogen. Attempts have been made for the utilization of molasses as a manure in Java, Hawaii, Queensland and other sugar-producing countries for a number of years. It has been reported that when molasses are added to growing plants harmful results are produced. This can be easily explained from the following considerations:—

The small amounts of nitrate, which is the real plant food present in the soil reacts with the carbohydrates present in the molasses with the formation of ammonium salts through the agency of bacteria, as is well known, or light as established by

Dhar and Mukerji. Moreover, the ammonium salts may be eaten up by the increased growth of the micro-organisms caused by the addition of energy-rich carbohydrates of the molasses. In this way the available nitrogen of the soil may be lost to the crops. Moreover, the oxidation of the carbohydrates generate heat in the soil and both these results may be prejudicial to the growth of plants. The workers at Java have shown empirically that the carbohydrates present in the molasses were the real factors in improving soil fertility, because the effect produced by equivalent amount of potash, phosphates, lime and combined nitrogen is insignificant. The experience of workers in other sugar-producing countries shows that an interval of some weeks between the addition of molasses to the soil and the growth of crops on this soil seems necessary. From our results it is clear that sufficient time is necessary for the oxidation of carbohydrates added with molasses leading to the maximum amount of ammonia formation and increase of total nitrogen in the soil. The carbohydrates must be oxidised in order that the nitrogen may be fixed and as this process takes time, an interval of 8 to 12 weeks depending on the amounts of molasses added is absolutely necessary.

The workers at Java have reported the formation of organic acids in the incipient stage after the addition of molasses to the soil. This observation has been confirmed by Bhaskaran Narasimghamurti, Subramanyan and Sundara Ayengar (*Proc. Indian Acad. Sci.*, 1934, **1**, 155) who have reported the production of acetic acid, propionic acid, butyric acid, etc., under water logged conditions. We have observed that traces of alcohol and small amounts of organic acids are produced when molasses or cane sugar are added to the soil in presence of air. But a good deal of the sugars added with molasses are oxidised completely to carbon dioxide and water. Most of the intermediate products are also energy-rich and are oxidised to carbon dioxide in course of time on the soil surface. Hence, large amounts of energy are available for the fixation of atmospheric nitrogen in the soil on the addition of molasses and proper aeration.

INFLUENCE OF AMMONIUM SALTS AND NITRATES ON NITROGEN FIXATION IN SOILS BY THE ADDITION OF MOLASSES.

A very important fact has been brought out by our researches—that the amount of ammonium salts obtained by fixation depends on the quantities of the available and possibly total nitrogen originally present in the soil before the addition of molasses or cane sugar. Thus in our first set of experiments with pure cane sugar when added to unsterile soil and exposed to sunlight, the ammoniacal nitrogen rose to 0·0186% from 0·00126% originally present in the soil, which contained 0·00164% available nitrogen. In the second series of experiments, the ammoniacal nitrogen increased from 0·00192% to 0·0162% and the total available nitrogen in the soil was 0·00392%.

Similarly with molasses, the fixation was less as it contained some ammonium salts.

Our results show that in presence of ammonium sulphate or potassium nitrate, the fixation of atmospheric nitrogen in the soil on the addition of cane sugar and molasses may be small.

It appears, therefore, that in soils containing a larger percentage of available nitrogen, the fixation due to the addition of energy-rich compounds is less marked. In tropical countries, however, the nitrogen fixation on the addition of molasses or other carbonaceous compounds is likely to be always prominent, as the ammonia and total nitrogen contents of tropical soils are low.

PROBABLE MECHANISM OF NITROGEN FIXATION.

It is believed that under both anaërobic and aërobic conditions, ammonia is the first product of nitrogen fixation, as ammonia is easily detected in the fixation of atmospheric nitrogen. Glucose has been found to decompose into pyruvic acid and hydrogen under anaërobic conditions according to the equation: $-C_6H_{12}O_6 = 2\,CH_3COCOOH + 2H_2 + 12$ Cal. In presence of the nitrogen of the atmosphere and on the soil surface, the hydrogen obtained from the decomposition of glucose may form ammonia according to the equation: $-N_2 + 3H_2 = 2NH_3 + 24$ Cal.

In presence of oxygen, however, that is, under aërobic conditions, it is difficult to assume that ammonia is also the first produce of nitrogen fixation. Because, in presence of oxygen, glucose can undergo one or more of the following oxidations on the soil surface:—

(1) $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 676$ Cal.

(2) $C_6H_{12}O_6 + 4\tfrac{1}{2}O_2 = \underset{\text{oxalic acid}}{3C_2H_2O_4} + 3H_2O + 493$ Cal.

(3) $C_6H_{12}O_6 + 1\tfrac{1}{2}O_2 = \underset{\text{citric acid}}{C_6H_8O_7} + 2H_2O + 199$ Cal.

(4) $C_6H_{12}O_6 + O_2 = \underset{\text{glycuronic acid}}{C_6H_{10}O_7} + H_2O + x$ Cal.

(5) $C_6H_{12}O_6 + \tfrac{1}{2}O_2 = \underset{\text{gluconic acid}}{C_6H_{12}O_7} + x$ Cal.

It seems that in presence of air, the first change (1) is the most important. The above organic acids, which may be produced under aërobic conditions and the organic acids (*e.g.*, acetic, propionic, butyric, lactic, etc.), and traces of alcohol, glycerol, etc., which may be generated in anaërobic conditions are also easily oxidized to carbonic acid on the soil surface liberating energy. Hence, a large quantity of energy is available on the soil surface for nitrogen fixation on the addition of molasses or cane sugar to soil exposed to air and light.

We have shown that in the photo-chemical or induced oxidation of carbohydrates in the complete absence of bacteria, ammonium salts are also produced. Hence in the soil containing compounds of iron, manganese, traces of titanium, copper, etc., which are excellent catalysts in oxidation reactions and exposed to sunlight and air, the oxidation of the carbohydrates added with molasses is certainly due to bacteria, light and chemical catalysts all acting simultaneously. For obtaining the hydrogen required for ammonia formation, the following reaction has to take place:—$H_2O = H + OH - 112$ Cal. The direct combination of nitrogen and oxygen forming nitric oxide according to the equation: —$N_2 + O_2 = 2\ NO - 43{\cdot}2$ Cal. appears to require less energy than the process leading to the formation of ammonia. It appears, that the iron compounds, traces of manganese and copper compounds and sunlight, which falls on the soil surface can facilitate the formation of nitric oxide from oxygen and nitrogen of the air. The nitric oxide can be readily oxidized to nitrous and nitric acids, which form nitrates in the soil.

Dhar and Mukerji (*J. Indian Chem. Soc.*, 1934, **11,** 727) have shown that solutions of nitrates and carbohydrates in presence of sunlight and titanium oxide can readily form small amounts of amino acids, with copious production of ammonium salts. It is interesting to note that ammonium salts and carbohydrates when exposed to the sunlight in presence of titanium oxide do not, however, form amino acids. It is well known that in plants the proteins, which are mostly the condensation products of amino acids, are only formed when carbohydrates have already accumulated by photo-synthesis. The carbohydrates formed by photo-synthesis in plants react with nitrates absorbed by plants from the soil and this results in the production of amino acids, proteins and ammonium salts in the plants. As a matter of fact, Waynick and Woodhouse (California, *Agric. Exp. Station Annual Report*, 1918-19, pp. 62-63) have obtained evidence of amino-acid formation in nitrogen fixation by Azotobacter. It is believed that in the first few days of the growth of Azotobacter amino acids accumulate and later on proteins increase. In our experiments with pure cultures of Azotobacter thriving in mannite we have been able to detect amino acids by the valuable "ninhydrin" test in the filtered liquids obtained by crushing the Azotobacter cells with sand in a pestle and mortar. According to Jodidi (*J. Amer. Chem. Soc.*, 1910, **32,** 396), Schreiner and Skiner, *U. S. Depart. Agr. Bur. Soils Bull.*, 1912, 87) and Lathrop (*J. Franklin Inst.*, 1917, **183,** 169, 303, 465), several amino acids are of common occurrence in the soil. These amino acids may be obtained either by the hydrolysis of proteins added to the soil as manure or formed synthetically as explained above. It seems likely, therefore, *in vitro* as well as in the plant and in the soil, the nitrate is reduced to ammonia by the action of carbohydrates or other carbonaceous compounds with simultaneous formation of amino acids in small quantities. Hence, it appears that nitrates are first produced in nitrogen fixation and the nitrates react with the energy-rich materials present in the soil with the formation of ammonium salts and small amounts of amino acids.

NO ANAEROBIC DENITRIFICATION ON THE ADDITION OF MOLASSES TO FIELDS.

Our field experiments as well as those carried on in dishes show that there is absolutely no anaërobic denitrification even when large quantities of molasses are added to soil exposed to air and light. The available nitrogen (sum of ammoniacal and nitric nitrogen) and the total nitrogen contents of the soil are never less than the original amounts present in the soil before the addition of molasses. As a matter of fact, even a few days after the addition of molasses to the soil, the ammoniacal nitrogen is appreciably increased and the available and total nitrogen contents also augment due to fixation of atmospheric nitrogen. When the amounts of molasses are large and the aëration of the soil inadequate, a part of the nitric nitrogen of the soil may be converted into ammoniacal nitrogen but it is never lost to the soil. The ammoniacal nitrogen, in course of time, is again oxidized to nitrate. This is a very important observation, which differs from the experience of workers in temperate climates. It has already been emphasised that the fixation of atmospheric nitrogen depends on the velocity of the oxidation of the energy-rich materials added to the soil and due to the sunlight and the high temperatures prevalent in tropical soils, the oxidation of the carbohydrates and other energy-rich compounds is much greater than in colder countries and hence in tropical countries, the soil condition from the view point of oxidation reactions are much more favourable than in temperate climates. Hence molasses even in large amounts when added to tropical soils, which are well aërated, always adds nitrogen to the soil and thus acts as an excellent fertiliser to crops and the question of anaërobic nitrogen loss from tropical soils does not arise.

Moreover, our experiments on compost formation with molasses show that the total nitrogen in the composts is double the amount originally present in the soil. The soil organic matter and humus and carbon are also considerably increased on the addition of molasses. Hence the increased nitrogen is stored in the soil and is available to plants, the soil organic matter acts as a preserver of the nitrogen. In a recent publication we have shown that the percentages of available nitrogen in tropical soils are greater in those of temperate climates. Hence the total nitrogen which is added to the soil due to nitrogen fixation on the addition of molasses, can partially be converted into the available form for absorption by plants. Due to the increase of carbon in the soil on the addition of molasses, the increased amounts of nitrogen arising out of fixation, are well preserved, as it has been proved in our experiments that molasses can preserve the nitrogen added to the soil as ammonium sulphate. Hence molasses, which adds both carbon and nitrogen to tropical soils, is a distinctly better fertiliser for tropical soils than ammonium sulphate. Our experiments on the addition of molasses to fields in two consecutive years show that there is a definite residual effect and hence it can be concluded that the nitrogen fixed is available to plants for two years. When large amounts of molasses are added, the residual

effect may last for more than two years. Hence molasses has several advantages over artificial nitrogenous manures.

Another interesting fact has been brought out by our researches that no flies or insects are attracted and no bad smell is given off even when 500 to 1000 maunds of molasses are added per acre of land exposed to light and air. It is well known that the soil surface is an excellent adsorbent. The organic substances and the products of their decomposition are readily adsorbed by the soil and they undergo decomposition readily into carbon dioxide and water and ammonia when the soil is properly aerated. Hence, molasses is a very suitable fertiliser for tropical countries, as it easily adds both combined nitrogen and humus, which are the crying need of tropical soils.

EFFICIENCY OF THE NITROGEN FIXATION PROCESSES OF DIFFERENT KINDS

It is well known that less than 1 per cent of the energy available in the oxidation of carbohydrates is utilised in the fixation of nitrogen in presence of Azotobacter. In the Table III it will be seen that the efficiency of nitrogen fixation in the induced oxidation of glucose or cane sugar in presence of ferrous hydroxide is of the same order as in the bacterial fixation. Further work on the efficiency of bacterial, photochemical and catalytic nitrogen fixation is in progress.

FIXATION OF NITROGEN IN ANIMAL AND PLANT RESPIRATION.

It is well known that about 400 grams of carbohydrates and about 50 grams of fat are oxidised in a man to supply the energy requirement per day. Is it likely that in this oxidation nitrogen fixation also takes place? The experiments of Landergren (*Skan Archives für Physiologie*, 1903, **14,** 112) show that with diets containing carbohydrates and fats, but scarcely any proteins, less than 4 grams of nitrogen are eliminated per day in urine. Moreover Catheart (*Biochem. Zeit.*, 1907, **6,** 109) has obtained a total nitrogen excretion of 2·84 grams with a diet of cream and starch. It appears, therefore, that in a diet consisting exclusively of fats and carbohydrates the nitrogen elimination is considerably decreased but cannot be altogether stopped. It is well known that carbohydrates and fats act as proteins sparer in the animal body, because they act as marked negative catalysts in the oxidation of proteins. It is quite possible that a part of the nitrogen elimination on a diet consisting exclusively of fats and carbohydrates may be due to the ammonia formed by nitrogen fixation in the animal body.

Similarly it seems probable that in the plant respiration also small quantities of nitrogen may be fixed.

RULES FOR USING MOLASSES AS MANURE FOR ORDINARY LAND.

The following rules produce good results with molasses as a fertilizer for increasing the nitrogen content of the soil:—

(1) Spread as uniformly as possible 100 to 300 maunds of molasses after mixing it with water per acre of land.

(2) Dig or turn the soil once every week or ten days after the application of molasses. Continue this digging for 2 or 2½ months and then sow the crop. Frequent digging or turning over the soil is necessary for the success of the experiment. If 500 to 1000 maunds of molasses per acre have to be used, digging or turning the soil has to be continued for four to five months before the sowing of the crop.

(3) Water the soil after the addition of molasses as frequently as you can manage.

(4) The oxygen of the air combines with the sugars of the molasses and liberates energy, which is necessary for the fixation of the nitrogen of the air in the soil. In this way the nitrogen of the air combines with the oxygen and forms nitrogenous compounds useful for plants and thus the soil fertility is increased. Oxygen is necessary for this process and the soil must be well aërated by turning it after the addition of molasses.

(5) Our experiments show that flies or insects are not attracted and no bad smell is produced even when 500 to 1000 maunds of molasses are applied to fields exposed to light and air. The carbohydrates and the other ingredients of the molasses are readily absorbed by the soil and undergo rapid decomposition and hence the question of a possible nuisance due to the addition of molasses to fields does not arise.

MOLASSES IN THE RECLAMATION OF ALKALI AND USAR LANDS.

It is estimated that the total area of *usar* lands in the United Provinces alone is more than 4,000,000 acres. Dr. J. A. Voelcker, who examined the extent of alkaline lands in Northern India, stated in his "*Improvement of Indian Agriculture*," London, 1893, p. 55, as follows:—"Enormous areas, especially in the plains of Northern India, are thus affected, and in the North-West Provinces alone there are between four and five thousand square miles of *usar* land." In the Punjab, in Behar and in the South of India, there are vast tracts of such unproductive lands. Naturally the reclamation of these lands is a problem of great importance to India. The salts, which make these lands unfit for growing crops, are the carbonate, sulphate and chloride of sodium, sodium carbonate is chiefly responsible for the unproductiveness of such lands, which are generally heavy clay soils and are very often termed *parti* or waste lands.

A considerable amount of research work has been carried on by Gedroiz in Russia, Hilgard in the Western parts of the United States, de' Sigmond in Hungary, Dymond in England and Hissink in the Zuider Zee area in Holland for the reclamation of alkali lands and those damaged by sea water in their respective countries. In these researches, 12 tons of gypsum, 20—30 cwt. of powdered sulphur and large amounts of ammonium sulphate per acre of alkali lands have been used in their reclamation. All these substances are too costly for India. In course of time, the sulphur added to the soil is oxidized to sulphuric acid by the joint action of bacteria, catalysts and light and hence the sodium carbonate of the alkaline soil is neutralized with the formation of sodium sulphate, which can be washed away by flooding the lands. Calcium sulphate when added to the alkali soils forms calcium carbonate and sodium sulphate, the latter can be removed by washing. The ammonium sulphate reacts with sodium carbonate forming ammonium carbonate, which readily decomposes and sodium sulphate, which can be dissolved away.

As molasses is distinctly acidic and as it forms organic acids like acetic, propionic, butyric, lactic, etc., when added to the soil, which is not much aërated, it was expected that molasses can be used in the reclamation of alkaline soils.

We have carried on comparative experiments in the reclamation of alkali soils by using gypsum, powdered sulphur and molasses.

Experiments in dishes with two samples of usar *soils collected from Phaphamau (near Allahabad).*

A. 1. 200 gms. soil + 8 gms. gypsum . .
2. 200 gms. soil + 8 gms. sulphur . .
3. 200 gms. soil + 14 gms. molasses . .

} added and exposed to sunlight in dishes mixed with water.

B. Exactly similar experiments with another sample of *usar* soil. *The Alkalinity of the soils after a week was as follows* (exposed to sunlight for 36 hours) :—

Original soil A		contained	... ... 0·00663% Na_2CO_3
Original soil B		contained	... ... 0·00504% „
Soil with gypsum,	A	„	... ... 0·00591% „
„	B	„	... ... 0·00451% „
Soil with powdered sulphur	A	„	... ... 0·00583% „
„	B	„	... ... 0·00445% „
Soil with molasses is acidic	A	„	... ... 0·00504 [H°]
„	B	„	... ... 0·00388 [H°]

After 3 Weeks (exposed to sunlight for 100 hours)

Soil with gypsum	A	contained	... ... 0·00583 Na_2CO_3
„	B	„	... ... 0·00124 „
Soil with sulphur	A	„	... ... 0·00530%
„	B	„	... ... 0·00397%

Soil with molasses is acidic	A	has	0·00572 [H⁰]
„	B	has	0·00437 [H⁰]

After 5 weeks (exposed to sunlight for 184 hours)

Soil with gypsum	A	contained	0·00328% Na_2CO_3
„	B	„	0·00364 „
Soil with sulphur	A	„	0·00291 „
„	B	„	0·00328 „
Soil with molasses is acidic	A	has	0·00033 [H⁰]
„	B	„	0·00427 [H⁰]

The above results show that the acidity of the *usar* soils treated with molasses and the alkalinity of the soils treated with gypsum and powdered sulphur decreases with time when exposed to air and light in dishes with frequent addition of distilled water.

Ammoniacal, nitric and total nitrogen contents of alkali soils before and after treatment with gypsum, powdered sulphur and molasses and exposed to sunlight.

	Ammoniacal nitrogen	Nitric nitrogen	Total available N.	Total nitrogen
Original soils.				
A	0·00301%	0·00352%	0·00653%	0·028%
B	0·00084	0·00096	0·0018	0·0082
Exposed soils for 60 hours to sunlight, analysed on the 28th October, 1935; soil with 7% molasses (containing 60% carbohydrates)				
A	0·00312	0·0032	0·00632	0·0294
B	0·00216	0·00096	0·00312	0·0085
Soil with 4% gypsum.				
A	0·00076	0·0032	0·00396	0·0277
B	0·00014	0·00096	0·00110	0·0077
Soil with 4% powdered sulphur.				
A	0·00084	0·00344	0·00424	0·028
B	0·0002	0·00096	0·00116	0·0077

Exposed soil to sunlight for 180 hours, analysed on the 20th November, 1935.

Soil with 7% molasses containing 60% carbohydrates.

	Ammoniacal nitrogen	Nitric nitrogen	Total nitrogen
B	0·0042%	0·00102	0·00921
A	0·00364	0·00342	0·0311
Soil with 4	% gypsum.		
B	0·00004	0·00096	0·00761
A	0·0004	0·00338	0·0262
Soil with 4	% powdered sulphur.		
B	0·0001	0·00096	0·00758
A	0·00042	0·0033	0·0255

These results show that the nitrogen of the alkaline soils increases on the addition of molasses but decreases when gypsum or powdered sulphur is added.

Baron Berthollet, one of the greatest luminaries of French Science, who accompanied Napoleon in his Egyptian expedition towards the end of the 18th century, was struck by the fact that solid sodium carbonate existed on the banks of the Nile. Being one of the founders of the law of mass action, Berthollet believed that the sodium carbonate was formed by the interaction of sodium chloride obtained by the flooding of the Nile and the calcium carbonate present in the soil. This hypothesis was supported by Hilgard and his colleagues in California, who are pioneers in the reclamation of alkali soils in the United States, and by the workers in the United States Bureau of Soils.

An ingenious explanation of the formation of sodium carbonate was offered by Paul de Mondesir in 1888. He was impressed by the fact that calcium chloride is obtainable in the aqueous extract of a soil situated near the sea. And he believed that it must have been formed by the action of sodium chloride on the soil. He tried to explain what happened to the sodium, which did not exist in the soluble state. In order to test this point, he treated soil with a solution of sodium chloride in the laboratory and could obtain calcium chloride and an insoluble sodium compound. When calcium chloride was removed by washing, the insoluble sodium compound is easily decomposed by the action of carbonic acid forming sodium carbonate. By the successive interaction of sodium chloride, water, carbonic acid, and water again, he was able to obtain 100 gms. of sodium carbonate from 1 kg. of soil. His experiments prove, therefore, that the sodium chloride does not react with calcium carbonate as was assumed by Berthollet, but it reacts with the soil forming a sodium

adsorption complex and calcium chloride, which can be removed by washing. The sodium adsorption complex can be decomposed by carbonic acid with the formation of sodium carbonate. This explanation of Paul de Mondesir has been developed and supported by the well-known Russian exponent of soil science, Dr. Gedroiz and is generally accepted.

Principles of Colloid Chemistry were utilized by Gedroiz in his investigations on alkali soils of Russia and their reclamation. Gedroiz observed that the amount of sodium carbonate that could be dissolved by adding water, decreased with successive addition of water. He concluded that the sodium carbonate existed in the adsorbed state in the soil. When the soil was treated with sodium sulphate or chloride the amount of sodium carbonate extracted with water increased. When sodium chloride and calcium carbonate were added to soil and extracted with water, small amounts of sodium carbonate were obtained. From his experiments Gedroiz concluded that the formation of sodium carbonate in the alkali soil proceeds in three stages—the first is the reaction between the sodium chloride and the soil, the second is the washing away of the soluble product and the third is the reaction between the insoluble sodium compound and the carbonate. The simplest explanation is to assume that the sodium chloride reacted with the zeolitic silicates forming a sodium clay, which reacts with the carbonate to form sodium carbonate and a calcium clay. This explanation of the formation of the alkaline soils leads us to a method of reclaiming them. Washing away of the carbonate with water is certainly inadequate as long as the clay remains a sodium one. The proper step should be the replacement of sodium by calcium and this was effected by Hilgard and his associates in California for the reclamation of alkali soils in the Western States of the United States. The alkali soil was treated with gypsum (calcium sulphate) and followed by flooding with water. 12 tons of gypsum per acre of soil were used and this led to the formation of sodium sulphate, which could be washed away and the sodium clay was converted into a calcium one. The gypsum treatment was also adopted in reclaiming large tracts of land in Russia according to the suggestion of Gedroiz and his colleagues.

Powdered sulphur at the rate of 20—30 cwt. per acre has been used with beneficial results for the reclamation of alkaline soils. By the joint action of bacteria and light the sulphur is oxidized in the soil forming sulphuric acid, which neutralizes the alkali present in the alkali soils. Ammonium sulphate has also been used and this reacts with calcium carbonate forming calcium sulphate, which can be washed out by flooding.

The reclamation of Hungarian alkali soils has been carried on by de'Sigmond. The soils containing sodium salts are reclaimed by reducing the evaporation from the surface of the soil and by growing lucerne, which requires large amounts of moisture and dries up the soil. In this way the upward movement of the salt is decreased. Press lime, gypsum, farmyard manure, etc., have also been used in dissolving the calcium carbonate.

Interesting results have been obtained by Dymond and his colleagues in England in the reclamation of the soil spoilt by sea water. They observed that the flooding of the land by sea water, at first kills the vegetation by the direct action of the salt. When the flood subsided and the rain started, the soils were washed resulting in a partial removal of the salts deposited from the sea water. At this stage, the soil was well-suited for a good crop yield. But when the soil was further washed by rain, it deteriorated as the small amounts of salts necessary for the flocculation of the clay particles were removed and the clayey soil did not subside for weeks, and hence cultivation was difficult. Dymond showed that calcium and magnesium of the soil were displaced by sodium from the salt water. The initial favourable effect was due to the coagulating action of the residual salt left on the clay. But when the salts were further washed away by rain, the lack of the presence of electrolytes caused the soil to be muddy and flocculation of the clay particles difficult.

Dutch investigators notably Hissink and his collaborators, from their experience in the Zuider Zee reclamation scheme, are in agreement with the observations of Dymond and his colleagues. Hissink has stated that the soil left after the sea water has drained away is infertile, because it contains sodium clay and in order to make it fertile it must be converted into a calcium clay. The Dutch soil contains enough calcium for the conversion of the sodium into a calcium clay, but the operation takes time.

The Dutch investigators have found that the soil in the Zuider Zee area contains sufficient amounts of calcium salts for the conversion of the sodium clay into the calcium one. In the first year, after the drainage of the sea water the soil is sticky, wet and infertile and unsuitable for vegetation. In the second year, the rain water removes a good deal of the salt and the soil dries up appreciably and is suitable for plant growth. But this state of affairs does not last long and in the third year practically all the salt is washed out, again making the soil sticky and unsatisfactory for cultivation. In the fourth year, the calcium compounds react with the sodium soil converting it a calcium one; thus the soil is made suitable for plant growth and at this stage the Dutch farmers begin their cultivation.

It will be evident from the aforesaid that much work has been done in the reclamation of alkali soils in the United States, Russia, Hungary, England, France and in Holland. No systematic work has, however, been carried out in this country in reclaiming large tracts of alkali soils in Northern India as well as in the sea water damaged lands in Sundar Bans in Bengal and in Gujrat, Bombay and Madras Presidencies.

As early as 1874, the Irrigation Department of the North-West Provinces was trying to reclaim *usar* lands and in 1877 a "Reh" Committee was appointed to investigate the problem. Subsequently, experiments were started at Awa in 1879, at Cawnpore in 1882 and at Aligarh in 1885. Unfortunately as no qualified chemist was associated in these experiments, no substantial results were obtained as is evident

from the following lines written by the Director of Agriculture, U. P., in his letter of November 13, 1935:—

> " *Usar* reclamation experiments were carried out by this Department at Juhi (Cawnpore) and Abbaspur (Unao) without appreciable results and the *babul* plantations at the places were transferred to the Forest Department. The matter may, therefore, be please referred to that Department."

The late Dr. J. W. Leather, who was the Imperial Agricultural Chemist, carried on the analysis of the scrapings from *usar* fields near Aligarh and other parts of U. P. and also tried to reclaim *usar* lands by applying gypsum. His results show that no wheat grows on soils containing 0·008% to 0·082% sodium carbonate even when treated with gypsum.

Leather's conclusions (*cf.* Investigations on *usar* land in the U. P. by J. W. Leather, Allahabad, 1914, p. 37) are as follows:—

(1) " The only experiment which can claim to have really reclaimed the *usar* land is the application of gypsum. The cost of sufficient gypsum to effect this was very great—about Rs. 700 or Rs. 800 per acre—and is obviously prohibitive. Even if the cost of gypsum could be reduced to one-half (what was employed cost about Rs. 20 per ton) it would still be too expensive if required in the quantity that this land did require it.

(2) " The effect of deep and good cultivation coupled with heavy manuring has not been either what is indicated to the unaided eye nor what might have been anticipated. The surface foot of soil has been apparently reclaimed, but below this the soil is as bad as ever.

(3) " Scraping off the salts is practically useless."

In the most highly impervious *usar* soils, Leather found 0·01% to 0·19% of sodium carbonate.

Recently Dr. Dalip Singh and Mr. S. D. Nijhawan (*Indian J. Agric. Sci.*, 1932, **2,** 1) have studied the *kallar* soils at Lyallpur, Lala Kaku, Montgomery, Bara Farm in the Punjab. They have reported that the alkaline soils available in these parts contain 0·63—1·07% of soluble salts in the first four feet and the following ingredients:— Insoluble residue 79%; soluble silica 0·2%; Fe_2O_3 4·25%; Al_2O_3 5·8%; CaO 3·84%; MgO 2·2%; Na_2O 0·56%; K_2O 0·76%; P_2O_5 0·25%; N 0·026%; organic matter 0·35%. These authors treated the alkali soils with a mixture of calcium chloride and calcium sulphate and reported an increase of permeability after 4 years, the addition of the calcium salts being continued every year. The p_H was 9 before and it became 8·2 after treatment. Normal soils contain 0·1% calcium as exchangeable base and sodium 0·06% to 0·10%. The exchangable calcium before treatment were 0·03% to 0·05% and after treatment it was 0·06% to 0·11% and sodium 0·3% to 0·5%.

Our results show that for the reclamation of alkali soils of the dry tracts of Northern India, molasses can be very usefully applied. It is well known that molasses contains between 60 to 70 per cent of carbohydrates, 4·5% potash, 2% lime, 0·5% phosphoric acid, 0·5% silica, 0·5% iron and aluminium oxides and 0·5% combined nitrogen and the rest, water. Moreover, molasses is distinctly acidic. Research work carried on in Allahabad, Bangalore, Java, Hawaii and other sugar-producing countries shows that when molasses is added to the soil, along with carbonic acid, organic acids like acetic, propionic, butyric, lactic, etc., are produced in the early stages in the decomposition and partial oxidation of the carbohydrates present in molasses. Consequently the acids present in molasses and those obtained from the decomposition and partial oxidation can neutralize the alkali of the soils rich in alkali. Moreover, the carbonic acid, which is produced in large amounts from the decomposition and oxidation of the carbohydrates can convert the sodium carbonate into bicarbonate. Also, in the process of the escape of carbonic acid from the molassed soil, the latter is rendered porous and its tilth is improved. The investigations at Allahabad show definitely that the moisture content of the molassed soil is appreciably higher than that of the unmolassed one. The lime which is added to the soil along with the molasses is rendered soluble by the organic acids formed from molasses and is helpful in the conversion of the sodium soil into the calcium one.

In publications on the utilization of molasses as a fertilizer, we have shown that ammonium salts and total nitrogen are increased when molasses is added to the soil, which has been aerated by ploughing. It has been established that the energy set free in the oxidation of the carbohydrates of the molasses is utilized in the fixation of the atmospheric nitrogen in the soil. The oxidation of the carbohydrates in the molasses leading to nitrogen fixation can be effected through the agency of bacteria (azotobacter), sunlight, inductors and catalysts like iron, copper, manganese, and titanium compounds. All these substances are present in the soil under normal conditions. Hence along with the neutralization of the sodium carbonate of the alkali soils by the acids produced in the decomposition and partial oxidation of the carbohydrates of the molasses, appreciable amounts of ammonium salts and proteins are added to the soil, which is thus rendered fertile. The acetate, propionate, butyrate, lactate, etc., produced in the neutralization of the organic acids obtained from molasses and sodium carbonate of the alkaline soils are also oxidised in the soil in course of time, liberating further energy to be utilized in the fixation of atmospheric nitrogen.

It is well known that when energy-rich substances like carbohydrates, proteins, etc., are added to the soil, its microbial population is greatly increased, as the micro-organisms can utilize the energy-rich compounds as food for their growth and multiplication. The micro-organisms are helpful in the decomposition of the soil organic compounds, and in the conservation of the nitrogen and thus the porosity and fertility of the soil is increased. The workers at Allahabad and at Java have shown that

the fertilizing action of molasses, when added to ordinary soils, is due almost exclusively to the carbohydrates existing in the molasses, as it has been established that the effect produced by equivalent amounts of nitrogenous compounds, potash, and phosphate on the growth of vegetation is exceedingly small in comparison with the effect produced with molasses.

Molasses to the extent of 100—500 maunds per acre has been applied in some alkaline fields in Cawnpore and other places in the United Provinces in two consecutive years and three months after the second application an excellent crop of sunn-hemp and other plants were obtained, where no vegetation could be grown due to the high alkalinity of the soil. If larger quantity of molasses could be used, say 500 to 1000 maunds per acre on the alkali soil, plants can be grown in such soils six months after the application of the molasses. The soil should be ploughed before the application of molasses. After applying molasses, the land should be watered and should be dug or turned over once every month. It is clear, therefore, that over and above, the well-known methods available for the reclamation of alkali soils (*e.g.*, addition of powdered sulphur, gypsum, ammonium sulphate, etc.), molasses can be utilized in the reclamation of alkali soils. This process should be useful especially in areas near sugar factories. Molasses when added to the soil neutralizes the sodium carbonate of the alkali soils, increases the soil micro-organisms, the humus, the nitrogen and ammonia contents, and also the water-retention capacity and the calcium salts, which are readily soluble. Moreover, it improves the soil tilth and humus content. The calcium added with molasses also helps in the conversion of the sodium clay into the calcium one and all these go towards the reclamation of the alkali soils on the addition of molasses.

The soluble calcium salts are helpful in the improvement of the soil tilth by their flocculating power on the clay particles. Moreover, in presence of soluble calcium salts, the permeability of the soil is greatly improved. Our results show that molasses is a better reclaiming agent for alkaline lands than either gypsum or powdered sulphur, as there is nitrogen loss from soils when these latter reclaiming agents are added to alkaline soil, whilst molasses adds nitrogen. The reclaiming effect of molasses is much quicker than that of gypsum or powdered sulphur, because the acids formed from molasses neutralize the alkali quickly and the soluble calcium salts added with molasses improves the tilth and permeability of the soil. It has been reported that four years are necessary for reclaiming alkaline lands on treatment with gypsum or powdered sulphur but with molasses, four to six months are quite adequate.

Moreover, as the *usar* lands contain much less total nitrogen (0·02% as against 0·04% in normal soils) and as there is nitrogen loss from *usar* lands on the addition of gypsum or powdered sulphur, it seems improbable that these two substances could be used as reclaiming agents in tropical soils; they may be suitable for the soils of temperate countries as they contain more nitrogen (0·1% total nitrogen).

We have repeatedly observed that the pink colour of phenol phthalein obtained by adding this indicator to *usar* soil mixed with water is quickly destroyed by adding molasses.

We have carried on comparative experiments on the permeability of water through alkaline soils when treated with gypsum, powdered sulphur and molasses and we have observed that the permeability is increased to a greater extent on the addition of molasses to alkaline soils than with gypsum or powdered sulphur. Moreover, our experiments show that suspensions of alkaline soils in water readily coagulate with formation of aggregates, which settle very readily on the addition of molasses to the alkaline soil suspensions.

Presscakes from sugar factories containing large proportions of carbohydrates and calcium compounds are also very useful in the reclamation of alkali and *usar* lands.

It has been argued that the Indian cultivator being conservative, would not adopt molasses as fertilizer. To refute this argument against the use of molasses it is only necessary to quote the following lines from the important Government publication, Report on the Improvement of Indian Agriculture by Dr. J. A. Voelcker, who came out to India and studied the problem for over a year:—

"The Indian cultivator shows by the money which he is willing to pay for manure when able to afford it, that he is by no means ignorant of its value . . . . . . (page 95).

"At Mahim (Bombay) I found that Rs. 96 an acre was quite an ordinary amount to spend in manure for the 'garden' crops. Even larger sums than this are expended over *betel* vines, as much as Rs. 280 to Rs. 380 an acre being given out in manure, while for ginger, sugarcane, and plantains the cost frequently goes up to Rs. 160 per acre. At Poona, as much as Rs. 200 per acre is spent for sugarcane; at Amritsar, Rs. 43 an acre for the potato crop; at Hoshiarpur Rs. 60 an acre for sugarcane."

Even in England, there is plenty of scope for the improvement of Agriculture, as is evident from the following comment of *Nature*, August 10, 1935, on a recent lecture of Sir John Russell, the Director of the Rothamsted Experiment Station:—

"The history of British Agriculture shows that although men of enlightenment have seldom been lacking, progress has usually been extremely slow, owing to the crusted conservatism of the farming population. In the last hundred years, Science has done wonders in giving the farmer the means to increase production, but although he has used them to some extent, the potentialities, especially of fertilizers and of scientific breeding, still remain very great."

SUMMARY

1. When cane sugar solutions mixed with sterilized soil are exposed to sunlight for a long time in quartz vessels under sterile conditions, there is appreciable increase in the available and total nitrogen contents of the sterile soil.

2. Experiments show that 4 milligrams of nitrogen are fixed as ammonia per gram of glucose or cane sugar oxidized by passing air through solutions of these carbohydrates in presence of ferrous hydroxide. It appears that the efficiency of nitrogen fixation obtained in the induced oxidation of carbohydrates is of the same order as that with cultures of Azotobacter thriving in flasks.

3. When cane sugar solution is added to ordinary soils and exposed to sunlight and air, the ammoniacal and total nitrogen are increased.

4. When molasses in different amounts are added to soils in dishes and exposed to sunlight and air, the ammoniacal and total nitrogen are also increased. This increase of nitrogen is always greater in sunlight than in the dark.

5. Our experimental results show that in the photochemical or induced oxidation of carbohydrates, nitrogen fixation can take place. The oxidation of energy-rich organic compounds by air either by light absorption or by chemical induction or by bacterial action causes the fixation of atmospheric nitrogen. It appears, therefore, that in tropical countries in ordinary soils the fixation of atmospheric nitrogen by the addition of energy-rich compounds is partially bacterial and partially photochemical and catalytic.

6. Field experiments with molasses when mixed with soil, show that there is an appreciable increase in the total nitrogen and ammoniacal nitrogen contents. The amount of ammoniacal nitrogen goes on increasing up to a limiting value when it decreases. But at this stage, the nitric nitrogen increases due to the oxidation of the ammonium salts formed from nitrogen fixation, and the C : N ratio tends to approach the normal value. This is the time when crops are to be sown on the molassed fields. Using 10800 kilograms of molasses per acre of land and digging or turning over once in 10 days, the land is ready for crops in about 12 weeks, with 3600 to 7200 kilograms per acre, it is suitable in about 8 weeks. If quantities larger than 10800 kilograms of molasses per acre of land are added, about four to five months' interval will be necessary. In all our field trials with molasses as a fertilizer we have always observed an increase of total and available nitrogen. Moreover, as molasses contain potash, phosphate, lime and as nitrogen is fixed in molassed lands, it is an excellent fertilizer for tropical soils.

7. The moisture content of molassed lands is always greater than in the unmolassed ones.

8. Excellent composts containing double the amount of total nitrogen as is originally present in the soil have been obtained by mixing molasses with soil in heaps, which are exposed to air and light. The soil organic matter and humus and carbon are also considerably increased on the addition of molasses.

9. The available and total nitrogen of soils, which have been molassed for two consecutive years, are greater than in soils molassed once. It seems, therefore, that molasses exert a residual effect on the soil.

10. This new method of nitrogen fixation based on the principle of the utilization of the energy available from the oxidation of carbohydrates and other organic compounds in the soil should be largely utilized in tropical countries, where the velocity of the oxidation of substances in the soil is high under ordinary conditions due to the high temperatures and light absorption.

11. In cold countries, the soil temperature being low and due to lack of sunshine, the velocity of the oxidation of energy-rich substances present in the molasses may be small and thus the energy available from the oxidation of carbohydrates may be too small for any marked nitrogen fixation. Moreover, in temperate climates, Azotobacter is not suitable for nitrogen fixation, as our experiments and those carried on in other countries show that nitrogen fixation by Azotobacter at 10° and lower temperatures is practically nothing and Azotobacter requires more heat than most other bacteria and that is why Azotobacter has not been utilized by agriculturists in cold countries for nitrogen fixation.

12. Azotobacter should be widely utilized in the fixation of atmospheric nitrogen in the soil of tropical countries, when fed with energy-rich substances like molasses, presscakes, etc.

13. Our results obtained with ammonium sulphate added to the soil with and without molasses show that the total and available nitrogen of the molassed plots are always greater than those in the unmolassed plots. Hence molasses not only fix nitrogen in the soil but also acts as a sparer of nitrogen in the soil and this is a very important application of molasses. In tropical countries a mixture of molasses and ammonium salts is a better fertilizer than ammonium salt alone.

14. Cane sugar has also been found to act as a sparer of soil nitrogen. When molasses or cane sugar is added even in large quantities to the soil exposed to light and air, there is no evidence of anaerobic denitrification in all our experiments, although it has been generally believed that in such cases, anaerobic denitrification sets in.

15. Molasses has been found to be a better reclaiming agent for alkaline fields than gypsum or powdered sulphur.

16. It appears probable that nitrogen fixation takes place in animal or plant respiration.

17. It appears that in aerobic nitrogen fixation through the agencies of bacteria, light and chemical induction, the nitrogen and oxygen combine forming nitrate, which in its turn is converted into ammonia and small amounts of amino acids.

18. Greater yields of rice and sugarcane have been obtained with molasses as a manure.

19. The existing methods of utilizing molasses (*e.g.*, manufacture of power alcohol, acetic acid, etc.) are inadequate for the disposal of the total production of this substance in India. Hence it should be used as a manure.

20. Our experiments as well as those carried on in Java show that the increased fertility of the soil on the addition of molasses is chiefly due to the carbohydrates present in the molasses, as an equivalent amount of minerals and combined nitrogen as present in molasses produce very slight effect in improving the crop yield. It is quite clear from our experiments that the nitrogen fixed on the addition of molasses to the soil is the chief cause of the increased soil fertility observed on the addition of molasses. Hence, the process in which the molasses is burnt and the potash is utilized as manure, is unsatisfactory.

21. Experimental results show that molasses when added to alkali soils and watered converts the alkali soils into acidic ones.

22. The carbohydrates present in molasses when mixed with soil, which is not sufficiently aerated, are partially oxidized to carbonic acid and partially converted into organic acids (*e.g.*, acetic, lactic, propionic, butyric, etc.). These organic acids neutralize the alkali of the alkali lands.

23. The acetates, propionates, lactates, etc., formed in the neutralization of the alkali and the organic acids are oxidized to carbonic acid on the soil surface in course of time. In the oxidation of the carbohydrates and the organic acids and their salts, energy is set free and this is utilized in nitrogen fixation in soils.

24. The soluble calcium salts added with molasses flocculate the clay particles readily, and hence improves the permeability and tilth of the soil.

25. The bacterial population of molassed soils is greater than that of the unmolassed ones. All these factors are useful in the reclamation of alkali and *usar* lands.

Figures show that 1·2 acres of land under cultivation are available for each head of the population in India as against 2·6 acres in the United States and 2·3 acres in France. Hence we have to face the plain fact that we have in this country one-half the area of cultivated land for a unit of population.

It would appear from what has already been said that utilization of molasses and presscakes as fertilizer and as reclaiming agents of alkaline lands will solve

both problems—the difficulty in the proper disposal and the supply of combined nitrogen to the soil and make more land available for cultivation and thus increase the output of crop. The masses of the Indian population could thus be better nourished and their standard of living raised above subsistence level.

As we all know the Indo-Gangetic plain covers most of the sugarcane and other crop-growing area in this country. Allahabad, which is rather centrally situated, is thus admirably suited to be a centre for research on fertilizers and allied problems.

It has been my earnest desire and ambition to help in building up a great centre for Agricultural research in Allahabad where chemists and other scientists from different parts could work together and establish a liaison with the tillers of the land in lessening their difficulties and improving the yield. I am trying to do my humble bit in this matter and have already procured land on which I am erecting a laboratory, which is now almost ready. The need for establishing a research centre where chemists, agriculturists and tillers of land would cooperate to improve the crop yield cannot be over-rated. The matter is one of utmost importance to the cultivators as well as the population in general, so the Government and the public may naturally be expected to take an effective interest in the proposed scheme. May I respectfully appeal to the Head of our Government and to the public for support of this scheme?

Speech delivered by His Excellency Sir HARRY HAIG, K.C.S.I., C.I.E., I.C.S., Governor of the United Provinces of Agra and Oudh, at the Fifth Annual Meeting of the Academy of Sciences, United Provinces of Agra and Oudh, Allahabad, on Thursday, 19th December, 1935.

YOUR President has been kind enough to welcome me to your Fifth Annual Meeting, and I appreciate highly the opportunity of coming in contact with the Academy of Sciences. Allahabad, as I have come to realize more vividly in these last weeks, is a great centre of intellectual activity, and it is not unnatural that this Academy with its headquarters in Allahabad should be able to claim for itself an all-India status. As Patron of this Academy I am not expected to have any special knowledge of science. The functions of a patron, I understand, are limited to providing some support. Even in this respect I am perhaps inadequately equipped. Governors, it is true, are supposed to have something to do with the loosening and tightening of the public purse strings. But that process is not of much significance when the purse is empty. However that may be, you have my very good wishes, and, as the poet says,

"Evermore thanks, the exchequer of the poor."

It is fortunately not necessary to be a man of science to appreciate what science has done and is doing not merely for the advancement of knowledge in general, but in placing before us new processes and new devices for dealing with the otherwise intractable material facts of life. Those facts present a constant challenge to the inventive mind, and offer to science a series of problems which may be said to be continually expanding. Your President has devoted his address this afternoon to one of these problems which is of the greatest importance to this province and has explained in language, which he has been kind enough to keep as untechnical as possible, the conclusions of scientific enquiry and experiment upon it. Those conclusions are of great interest, and open out a fascinating vista of developments in our agricultural practice. The conclusions of Professor Dhar are new to me, but it is clearly necessary for the local Government to examine most carefully the economics of their application to practical agriculture.

The surgarcane crop is one of the most important and profitable in this province and its rapid development in recent years has been the most striking and hopeful feature in our agriculture. This development has naturally given rise to many problems, not the least of which is the necessity of putting back into the land in some form of fertilizer what is taken from it in considerable quantities by this crop. It is what is known as an exhausting crop, and there is a danger that the

agriculturist may, by growing it, use up the capital resources of his land, unless he takes appropriate measures. Professor Dhar now holds out the attractive prospect of putting back into the land by means of a by-product of sugar what has been taken from it by the sugarcane crop. His researches offer at the same time the possibility of the solution of a problem that has been troubling the sugar manufacturer, and that is the disposal of molasses for which hitherto no satisfactory market has been obtained. If we could at one and the same time provide a market for the molasses turned out by our sugar factories, and a satisfactory and cheap fertilizer for the land which is growing sugarcane, a double benefit of very wide extent would be conferred on the province. I can only say that we shall be anxious to examine promptly the practical possibilities of Professor Dhar's scientific conclusions. Professor Dhar has also held out to us the hope of a new process of reclaiming the very considerable areas of alkaline lands in this province. Here again if practical experiment establishes the economic possibility of this process, the effect on our agriculture will be great.

Professor Dhar is hoping to build up in Allahabad an important centre for agricultural research. He is already erecting a laboratory as the first step in the development of this idea. I shall watch its future progress with the greatest interest. There are a large number of problems of agriculture which are awaiting thorough scientific investigation. Any scientific worker, who devotes his talents and interest to this field, may be sure that he will be making a contribution of great value to the improvement of the economic conditions of the millions who live in this province by the land.

Gentlemen, I am glad to have had the opportunity of meeting so many distinguished scientists gathered together at this Annual Meeting and to find that the Academy of Sciences has such a vigorous practical life as a focus of scientific knowledge. I wish it continued success in the future.

VOTE OF THANKS

In proposing the vote of thanks to His Excellency the Patron, the Hon'ble Sir Shah Mohammad Sulaiman, Kt., M.A., LL.D., Chief Justice, High Court, Allahabad and Fellow of the Academy of Sciences, U. P., spoke as follows:—

YOUR EXCELLENCY,

On behalf of the Fellows and the Members of the U. P. Academy of Sciences it is my pleasant duty to offer our thanks to Your Excellency and express our gratefulness that you have been pleased to find time in the midst of your multifarious engagements to preside over this session. On the occasion of such a gathering, the presence of the Governor of the Province, who is the Patron of the Academy, is a source of immense encouragement and a sure guarantee of the continued financial support of the Government.

The U. P. Academy was the first Academy of its kind to be established in this country, and can justly take pride in being the seniormost Academy of Sciences in India. With the warm blessings from eminent Mathematicians and Scientists of the world, this Academy was founded during the regime of His Excellency Sir Malcolm Hailey, who presided at its inaugural meeting. We all are indeed very glad to find that the same keen interest in this scientific institution is now continued by Your Excellency, and we confidently hope that this Academy will flourish under your distinguished patronage. With the help of substantial grants from the U. P. Government this Academy has been able to extend and increase its activities, and is soon to adopt an All-India constitution. It is our legitimate expectation that the Academy with its expansion will receive support from Your Excellency's Government in a still larger measure.

During the few years that the Academy of Sciences has been in existence it has been able to do valuable work and has received recognition and appreciation in Europe and America. Under the able guidance of its first President, Prof. M. N. Saha, a Scientist of International reputation, the Academy was soon to acquire a position of importance for itself. The indefatigable industry of its first General Secretaries, particularly of Prof. A. C. Banerji who was incharge of the office here, placed the organisation on a firm footing. The sincere devotion of its office bearers, particularly of the present General Secretary, Dr. P. L. Srivastava, ensures that the work of the Academy will be well looked after, and its Proceedings will serve as a useful medium for the publication of mathematical and scientific papers, for which the papers abroad cannot find space owing to the enormous output of work in their countries. The present President, Prof. N. R. Dhar, in his Presidential Address,

has given us the result of his valuable researches on the use of molasses for the fertilization of agricultural lands. As Your Excellency has observed the Indian sugar factories are finding it difficult to dispose of their waste molasses; and it is to be hoped that with the enormous growth of the sugar industry, the utilization of molasses on economical lines will meet a great need and help the development of Indian agriculture.

The Fellows and the Members of the Academy are deeply grateful to Your Excellency for taking the trouble to come to this Annual meeting, and we feel highly honoured by your presence. On behalf of all of us assembled here to-day I offer to Your Excellency our sincere thanks for your kind good wishes accorded to the Academy, which is undoubtedly an indispensable accompaniment of University research work. Ladies and gentlemen, I formally propose a hearty vote of thanks to His Excellency the Patron.

Prof. K. N. Bahl, in seconding the vote of thanks, stated that he wished many happy returns of the day in which the Patron of the Academy would be kind enough to preside over the annual gathering.

APPENDIX 1

ABSTRACTS OF THE PROCEEDINGS

The council expressed its deep gratitude to the Government of the United Provinces for the grant of Rs. 2,000 awarded to the Academy for the year 1935-36.

The council resolved that the rules and regulations of the Academy of Sciences, U. P., be duly changed in conformity with the Companies Act.

The council welcomed the proposal of the National Institute of Sciences of India regarding the cooperation of the Academy of Sciences, U. P., in the publication by the Institute of some sort of a *comptes rendus* containing summaries of papers published in India and resolved to send for publication in the Indian Science Abstracts the abstracts of papers as soon as they are published by the Academy. It resolved further that each author be requested to send brief typed abstract of his paper in duplicate for this purpose.

The council resolved that the Vice-Chancellor of the Allahabad University, Allahabad, be elected a Benefactor of the Academy of Sciences of the United Provinces of Agra and Oudh.

The council resolved that the volumes of the Proceedings of the Academy of Sciences, U. P., should be arranged from 1936 according to the calendar year and not according to the academic year as at present.

The following two members were elected Fellows of the Academy in the Fellows' meeting held on November 30, 1935 :—

1. The Hon'ble Sir Shah Mohammad Sulaiman, Kt., M.A., LL.D., Chief Justice, High Court of Judicature, Allahabad.
2. Dr. R. N. Ghosh, D. Sc., Lecturer, Physics Department, Allahabad University, Allahabad.

The following members were elected office-bearers and the Members of the Council for the year 1936 in the Annual Meeting held on December 19, 1935.

President

1. N. R. Dhar, D.Sc., F.I.C., I.E.S.

Vice-Presidents

2. K. N. Bahl, D.Sc., D.Phil.
3. A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S.

Hony. Treasurer

4. H. R. Mehra, M.Sc., Ph D.

General Secretaries

5. S. M. Sane, B.Sc., Ph.D.
6. P. L. Srivastava, M.A., D.Phil.

Foreign Secretary

7. B. Sahni, D.Sc., Sc.D., F.R.S., F.G.S., F.A.S.B.

Other Members of the Council

8. K. C. Mehta, M.Sc., Ph.D.
9. M. N. Saha, D Sc., F.R S.
10. S. S. Bhatnagar, O.B.E., D Sc.
11. Ch. Wali Mohammad, M.A., Ph D., I E S
12. Shri Ranjan, D.Sc.
13. Lt.-Col., R. N. Chopra, C.I.E., M B., I.M.S
14. C. W. B. Normand, D Sc., M A.
15. D. R. Bhattacharya, D.Sc., Ph D., F.Z.S.
16. P. K. Parija, M.A., B.Sc., I E S.

APPENDIX 2

LIST OF OFFICE-BEARERS AND MEMBERS OF THE COUNCIL 1935

President

1. N. R. Dhar, D.Sc., F.I.C., I. E. S.

Vice-Presidents

2. K. N. Bahl, D.Sc., D. Phil.
3. A. C. Banerji, M.A., M.Sc., F.R.A.S., I.E.S.

Hony. Treasurer

4. H. R. Mehra, Ph.D.

General Secretaries

5. S. M. Sane, B.Sc., Ph D.
6. P. L. Srivastava, M A., D.Phil.

Foreign Secretary

7. B. Sahni, D.Sc., Sc.D, F.R.S, F.G.S., F.A.S.B.

Other Members of the Council

8. K. C. Mehta, Ph.D.
9. M. N. Saha, F.R.S.
10. S. S. Joshi, D.Sc.
11. Ch. Wali Mohammad, M.A.. Ph D., I.E.S.
12. Shri Ranjan, D.Sc.
13. Rudolf Samuel, Ph.D.
14. J. A. Strang, M.A.
15. D. R. Bhattacharya, D.Sc., Ph.D., F.Z.S.
16. K. C. Pandya, Ph.D.

APPENDIX 3

ORDINARY MEMBERS

R.—Resident. N.—Non-Resident.

*—Denotes a Fellow.

†—Denotes a Fellow of the National Institute of Sciences of India

Date of Election		Alphabetical List of Ordinary Members
31-10-35	R	**Agarwal**, RAI AMAR NATH, Bari Kothi, Daraganj, Allahabad.
20-4-35	†N	**Ajrekar**, SHRIPAD LAKSHMAN, B.A., I.E.S., *Professor of Botany*, Gujarat College, Ahmedabad.
17-4-31	R	**Asundi**, R.K., PH.D., *Reader*, Physics Department, Muslim University, Aligarh.
10-5-35	†R	**Ayyangar**, G. N. RANGASWAMI, RAO BAHADUR, B.A., I.A.S., *Millets specialist to the Government of Madras*, Agricultural Research Institute, P.O. Lawley Road, Coimbatore.
1-1-30	†N*	**Bahl**, K.N., D.PHIL, D.Sc., *Professor of Zoology*, Lucknow University, Lucknow.
1-1-30	†R*	**Banerji**, A.C., M.A., M.Sc., F.R.A.S., I.E.S., *Professor of Mathematics*, Allahabad University, Allahabad.
29-2-32	R	**Banerji**, G.N., The Scientific Instrument Company, Ltd., Hornby Road, Bombay.
22-12-32	†N	**Banerji**, S.K., D.Sc., *Meteorologist*, Ganeshkhind Road, Poona 5.
17-4-31	N	**Basu**, SARADINDU, M.Sc., *Meteorologist*, Ganeshkhind Road, Poona 5.
31-10-35	R	**Bharadwaja**, YAJNAVALKYA, D.Sc., *Professor of Botany*, Hindu University, Benares.
19-3-31	R	**Bhargava**, SALIGRAM, M.Sc., *Reader*, Physics Department, Allahabad University, Allahabad.
17-4-31	R	**Bhargava**, VASHISHTA, M.Sc., I.C.S., *Sessions and Subordinate Judge*, Agra.
17-4-31	R	**Bhatia**, K.B., I.C.S., *Magistrate and Collector*, Shahjahanpur.
17-12-35	R	**Bhatia**, M.L., M.Sc., *Lecturer in Zoology*, Lucknow University Lucknow.
21-4-33	†N*	**Bhatnagar**, S.S., D.Sc., O.B.E., *Professor of Chemistry*, Government College, Lahore.
20-12-34	R	**Bhattacharya**, A.K., D.Sc., Chemistry Department, Allahabad University, Allahabad.
1-1-31	†R*	**Bhattacharya**, D.R., M.Sc., PH.D., Docteur ès Sciences, *Professor of Zoology*, Allahabad University, Allahabad.
17-4-31	R	**Bhattacharya**, D.P., M.Sc., Bareilly College, Bareilly.
31-10-35	N	**Biswas**, B.N., *Professor of Physics*, Raja Ram College, Kolhapur (S.M.C.)

Date of Election		Alphabetical List of Ordinary Members
31-10-35	†N	**Bose**, D.M., M.A., B.Sc., Ph.D., *Palit Professor of Physics*, University College of Science and Technology, 92 Upper Circular Road, Calcutta.
3-4-33	R	**Chand**, Tara, M.A , D. Phil., *Principal*, K. P. University College, Allahabad.
9-11-35	N	**Chak**, Chandramohan Nath, M.Sc., Teacher's Training College, Bombay.
31-10-35	N	**Chakravarty**, D.N., D.Sc , *Professor*, King Edward College, Amraoti, Berar.
10-5-35	†R	**Champion**, H.G., M.A , *Sylviculturist*, Imperial Forest Research Institute, Dehradun.
29-2-32	R	**Charan**, Shyama, M.A., M.Sc., Agra College, Agra.
1-1-30	†R*	**Chatterji**, G., M.Sc., *Meteorologist*, Upper Air Observatory, Agra
17-4-31	R	**Chatterji**, K.P , M Sc , A.I.C., F.C.S., *Reader*, Chemistry Department, Allahabad University, Allahabad.
17-4-31	R	**Chatterji**, A.C., D.Sc., Dr. Ing , Chemistry Department, Lucknow University, Lucknow.
9-2-31	R	**Chaturvedi**, Champa Ram, Pandit, *Professor of Mathematics*, St. John's College, Agra.
31-10-35	†N	**Chaudhury**, H., M.Sc., Ph.D., D.I.C , *Head of the Department of University Teaching in Botany*, Punjab University, Lahore.
17-4-31	R	**Chaudhury**, H.P., M.Sc., Lucknow University, Lucknow.
17-12-35	R	**Chaudhury**, K. Ahmad, M.Sc., *Wood Technologist*, Imperial Forest Research Institute, Dehra Dun.
19-3-31	R	**Chaudhury**, Rabindra Nath, M.Sc., M.A., Mathematics Department, Allahabad University, Allahabad.
10-5-35	†N	**Chopra**, R.N., Lt.-Col., C.I.E., M.B., I.M.S., *Director*, School of Tropical Medicine, Central Avenue, Calcutta.
31-10-35	N	**Dabadghao**, V.M., Physics Department, College of Science, Nagpur.
19-3-31	R	**Das**, Ramsaran, D.Sc., Zoology Department, Allahabad University, Allahabad.
17-4-31	R	**Das**, C. Maya, M A., B.Sc , I.A.S., *Late Principal*, Agricultural College, Cawnpore.
28-10-32	N	**Das**, A.K., D.Sc., Alipore Observatory, Alipore, Calcutta.
22-12-32	N	**Das**, B.K., D.Sc., *Professor of Zoology*, Osmania University, Hyderabad, Deccan.
17-12-35	R	**Das Gupta**, S.N., M Sc., D.I.C., Ph D., *Reader in Botany*, Lucknow University, Lucknow.
15-9-31	R	**Dasannacharya**, B., Ph.D., *Professor of Physics*, Benares Hindu University, Benares.
17-4-31	R	**Deodhar**, D.B., Ph.D., *Reader*, Physics Department, Lucknow University, Lucknow.
31-10-35	N	**Desai**, M.S , M.Sc., *Professor of Physics*, M.T.B. College, Surat.
17-4-31	R	**Dey**, P.K., M.Sc., I.A.S., *Plant Pathologist to Government, United Provinces*, Nawabganj, Cawnpore.
29-2-32	N	**Deb**, Suresh Chandra, D.Sc., *Research Physicist*, Bose Institute, Calcutta.
1-1-30	†R*	**Dhar**, N. R., D.Sc., Docteur ès Sciences, F.I.C., I.E.S , *Professor of Chemistry*, Allahabad University, Allahabad.
31-10-35	R	**Dube**, Ganesh Prasad, M.Sc., *Lecturer in Physics*, Balwant Rajput College, Agra.
19-3-31	R	**Dutt**, S K., M.Sc., Zoology Department, Allahabad University, Allahabad.

Date of Election		Alphabetical List of Ordinary Members
17-4-31	†R	**Dutt**, S.B., D.Sc., *Reader*, Chemistry Department, Allahabad University, Allahabad.
28-10-32	N	**Dutt**, A.K., D.Sc., *Research Physicist*, Bose Institute, Calcutta.
22-2-33	R	**Ghatak**, NARENDRANATH, M.Sc., D.Sc., *Chemical Assistant to Indian Stores Department*, Government Test House, Alipore, Calcutta.
19-4-31	R	**Ghosh**, B.N., M.Sc., St. Andrew's College, Gorakhpur.
8-11-33	†N*	**Ghosh**, J.C., D.Sc., *Professor of Chemistry*, The University, Dacca.
19-3-31	R*	**Ghosh**, R.N., D.Sc., Physics Department, Allahabad University, Allahabad.
19-3-31	R	**Ghosh**, SATYESHWAR, D.Sc., Chemistry Department, Allahabad University, Allahabad
15-9-31	N	**Gogate**, D. V., M.Sc., Baroda College, Baroda.
15-9-31	R	**Gordon**, C. B., B.A., Christ Church College, Cawnpore.
31-10-35	R	**Gulatee**, B. L., M.A., *Mathematical Advisor*, Survey of India, Dehra Dun.
17-4-31	R	**Gupta**, B.M., PH.D., *Deputy Public Analyst to Government, United Provinces*, Lucknow.
17-4-31	R	**Higginbottom**, SAM, D.PHIL., *Principal*, Allahabad Agricultural Institute, Naini, E. I. R., Allahabad
17-4-31	R*	**Hunter**, ROBERT F., D.Sc., PH.D., *Professor of Chemistry*, Muslim University, Aligarh.
3-4-34	R	**Joshi**, A.D., P.E.S., *Lecturer*, Training College, Allahabad
21-12-31	R	**Joshi**, S.S., D.Sc., *Professor of Chemistry*, Benares Hindu University, Benares.
15-9-31	†N	**Kichlu**, P.K., D.Sc., Department of Physics, Government College, Lahore.
1-1-30	†R*	**King**, C.A., B.Sc. (Hons.), A.R.C.Sc., M.I.M.E., *Principal*, Engineering College, Benares Hindu University, Benares.
21-4-33	N	**Kishen**, JAI, M.Sc., *Professor of Physics*, S.D. College, Lahore.
9-2-34	N	**Kothari**, D.S., M.Sc., PH.D., *Professor of Physics*, The University, Delhi.
3-4-34	†R	**Krishna**, SHRI, PH.D., D.Sc., F.I.C., *Forest Biochemist*, Imperial Forest Research Institute, Dehra Dun.
5-10-33	R	**Kureishy**, A.M., M.A., *Reader in Mathematics*, Muslim University, Aligarh.
31-10-35	R	**Lal**, RAJENDRA BIHARI, M.Sc., *Assistant Traffic Superintendent*, E.I.R., Allahabad
20-4-35	†N	**Mahalanobis**, P.C., M.A., I.E.S., *Professor of Physics*, Statistical Laboratory, Presidency College, Calcutta
1-1-30	†R*	**MacMahon**, P.S., B.Sc. (Hons.), M.Sc., *Professor of Chemistry*, Lucknow University, Lucknow.
31-10-35	†R	**Maheshwari**, PANCHANAN, D.Sc., *Associate Professor of Botany*, Agra College, Agra.
31-10-35	N	**Majumdar**, R.C., M.Sc., PH.D., Department of Physics, University of Punjab, Lahore.
26-9-34	R	**Malaviya**, BRAJ KISHORE, M.Sc., Public Health Department, Allahabad Municipal Board, Allahabad.
1-1-30	†R*	**Mathur**, K.K., B.Sc. (Hons.), A.R.S.M., *Professor of Geology*, Benares Hindu University, Benares.
31-10-35	R	**Mathur**, K.N., D.Sc., *Lecturer in Physics*, Lucknow University, Lucknow.
31-10-35	R	**Mathur**, LAKSHMI SAHAY, M.Sc., Physics Department, Allahabad University, Allahabad.

Date of Election		Alphabetical List of Ordinary Members
17-12-35	†N	**Matthai,** GEORGE, M.A., SC.D., F.R.S.E., I.E.S., *Professor of Zoology,* Punjab University, Lahore.
1-1-30	†R*	**Mehta,** K.C., PH.D., M.SC., Agra College, Agra.
1-1-30	R*	**Mitter,** J.H., M.SC., PH.D., *Professor of Botany,* Allahabad University, Allahabad.
15-9-31	R	**Mathur,** L.P., M.SC., St. John's College, Agra.
8-11-33	N	**Mathur,** RAM BEHARI, M.SC., *Professor of Mathematics,* St. Stephen's College, Delhi.
19-3-31	R	**Mazumdar.** KANAKENDU, D.SC., Physics Department, Allahabad University, Allahabad.
19-3-31	†R*	**Mehra,** H.R., PH.D., *Reader,* Zoology Department, Allahabad University, Allahabad.
16-8-35	R	**Mehrotra,** BRAJ MOHAN, M.A., PH.D., Mathematics Department, Benares Hindu University, Benares.
21-12-31	R	**Mehta,** N.C., I.C.S., *Secretary, Imperial Council of Agricultural Research,* New Delhi.
21-4-33	N	**Mela** RAM, M.SC., *Asst. Professor of Physics,* Foreman Christian College, Lahore.
31-10-35	R	**Mohan,** ANANDA, B.SC., *Assistant Traffic Superintendent,* E.I.R., Allahabad.
31-10-35	R	**Mohan,** PIARE, M.SC., Department of Mathematics, Allahabad University, Allahabad.
20-4-35	†N	**Mowdawalla,** F.N., M.A., M.I.E.E., Mem. A.I.E.E., M.I.E., *Chief Electrical Engineer,* Bangalore.
21-4-33	N	**Mukerjee,** ASHUTOSH, M.A., *Principal,* Science College, P.O. Bankipore (Patna).
31-10-35	N	**Mukerji,** S., D.SC., *Kala Azar Enquiry,* School of Tropical Medicine, Calcutta.
1-1-30	R*	**Narayan,** LUXMI, D.SC., *Reader,* Mathematics Department, Lucknow University, Lucknow.
22-2-33	R	**Narliker,** V.V., M.A., *Professor of Mathematics,* Benares Hindu University, Benares.
17-4-31	R	**Nehru,** S.S., M.A., PH.D., I.C.S., Magistrate and Collector, (on leave)
20-4-35	†N	**Normand,** C. W. B., M.A., D.SC., *Director General of Observatories,* Poona.
31-10-35	R	**Oak,** V. G., M.SC., I.C.S., *Joint Magistrate,* Muttra.
17-4-31	R	**Pandya,** K. C., PH.D., St. John's College, Agra.
16-8-35	R	**Pande,** KEDAR DAT, M.SC., *Lecturer in Mathematics,* St. John's College, Agra.
3-4-33	†N	**Parija,** P. K., M.A., I.E.S., Ravenshaw College, Cuttack.
10-5-35	†N	**Pinfold,** ERNEST SHEPPARD, M.A., F.G.S., *Geologist,* Attock Oil Co. Ld., Rawalpindi.
18-9-35	N	**Pramanik,** S. K., M.SC., PH.D., D.I.C., *Meteorologist,* Meteorological Office, Karachi.
5-10-33	R	**Prasad,** GORAKH, D.SC., *Reader in Mathematics,* Allahabad University, Allahabad.
16-8-35	R	**Prasad,** JALPA, M.SC., Chemistry Department, K. P. Inter College, Allahabad.
21-4-33	N	**Prasad,** KAMTA, M.A., M.SC., *Professor of Physics* Science College, P.O. Bankipore (Patna)
15-9-31	†N	**Prasad,** MATA, D.SC., Royal Institute of Science, Bombay.
3-1-33	R*	**Prasad,** BADRI NATH, PH.D., Docteur ès Sciences, Mathematics Department, Allahabad University, Allahabad.

Date of Election		Alphabetical List of Ordinary Members.
17-4-31	R	**Puri**, B. D., M.A., Thomason Civil Engineering College, Roorkee.
22-12-32	†N	**Qureshi**, M., M.Sc., Ph.D., *Professor of Chemistry*, Osmania University College, Hyderabad, Deccan.
20-12-34	R	**Rai**, Ram Niwas, M.Sc., Physics Department, Allahabad University, Allahabad.
3-4-33	R	**Ram**, Raja, M.A., B.E., *Malarial Engineer*, Kasauli.
19-3-31	R*	**Ranjan**, Shri, M.Sc., Docteur ès Sciences, *Reader*, Botany Department, Allahabad University, Allahabad.
15-9-31	N	**Rao**, A. Subba, D.Sc., Medical College, Mysore.
22-2-33	N	**Rao**, G. Gopala, B.A., M.Sc., D.Sc., Chemistry Department, Andhra University, Waltair
21-12-31	R	**Rao**, D. H. Ramchandra, B.E., A.M.I.E., *Engineer*, Allahabad University, Allahabad.
20-4-35	N	**Rao**, I. Rama Krishna, M.A., Ph.D., D.Sc., Department of Physics, Andhra University, Waltair.
14-3-34	N	**Rao**, K. Rangadhama, B.Sc., Physics Department, Andhra University, Waltair.
22-2-33	N	**Ray**, Bidhubhusan, D.Sc., 92 Upper Circular Road, Calcutta.
21-12-31	R	**Ray**, Satyendra Nath, M.Sc., Physics Department, Lucknow University, Lucknow.
1-1-30	R*	**Richards**, P.B., A.R.C.S., F.E.S., *Entomologist to the Government*, United Provinces, Cawnpore.
1-1-30	†R*	**Saha**, M.N., D.Sc., F.R.S., F.A.S.B., F. Inst.P., P.R.S., *Professor of Physics*, Allahabad University, Allahabad.
29-2-32	R	**Saha**, Jogendra Mohan, M.Sc., *Manager*, Srikrishna Desi Sugar Works, Jhusi, (Allahabad).
1-1-30	†R*	**Sahni**, B., D.Sc., Sc.D., F.R.S., F.G.S., F.A.S.B., *Professor of Botany*, Lucknow University, Lucknow.
17-4-31	R*	**Samuel**, Rudolf, Ph.D., *Professor of Physics*, Muslim University, Aligarh.
17-4-31	R	**Sane**, S. M., B.Sc., Ph.D., *Reader*, Chemistry Department, Lucknow University, Badshah Bagh, Lucknow.
31-10-35	†N	**Sen**, Jitendra Mohan, M.Ed., B.Sc., Teacher's Dip., F.R.G.S., D.Ed., *Assistant Director of Education, Bengal*, Calcutta.
3-4-33	R	**Sen**, K. C., D.Sc., Imperial Institute of Veterinary Research, Muktesar, Kumaun.
20-4-35	†N	**Sen**, Nikhil Ranjan, D.Sc., *Professor of Mathematics*, 92 Upper Circular Road, Calcutta.
17-12-35	†R	**Sen Gupta**, N. N., Ph.D., *Professor of Psychology*, Lucknow University, Lucknow.
20-12-34	N	**Sen Gupta**, P. K., D.Sc., *Professor of Physics*, Rajaram College, Kolhapur. (Bombay Presidency).
21-4-33	N	**Seth**, J. B., M.A., Government College, Lahore.
17-4-31	R	**Seth**, S. D., M.Sc., Christ Church College, Cawnpore.
1-1-30	R*	**Sethi**, R. L., M.Sc., M.R.A.S., *Economic Botanist to Government*, United Provinces, Cawnpore.
19-3-31	R	**Sethi**, Nihal Karan, D.Sc., Agra College, Agra.
31-10-35	N	**Shabde**, N. G., D.Sc., *Professor of Mathematics*, College of Science, Nagpur.
3-4-34	R	**Shah**, S. M., M.A., Mathematics Department, Muslim University, Aligarh, U. P.
31-10-35	R	**Sharma**, P. N., M.Sc., Physics Department, Lucknow University, Lucknow.

Date of Election.		Alphabetical List of Ordinary Members
15-9-31	R	**Sharma**, Ram Kishore, M.Sc., Physics Department, Ewing Christian College, Allahabad.
18-9-35	R	**Shukla**, Janardan Prasad, M.Sc., *Manufacturing Chemist*, Oudh Sugar Mills, Hargaon, (R. K. Ry.) U. P.
3-4-33	N	**Siddiqi**, M. R., Ph.D., *Professor of Mathematics*, Osmania University, Hyderabad, Deccan.
3-4-33	R	**Siddiqui**, Mohammad Abdul Hamid, M.B.B.S., M.S., F.R.C.S., D.L.O., *Professor of Anatomy*, King George's Medical College, Lucknow.
17-4-31	R	**Singh**, Avadhesh Narain, D.Sc., Department of Mathematics, Lucknow University, Lucknow.
17-12-35	R	**Singh**, Bhola Nath, D.Sc., *Kapurthala Professor of Agricultural Botany and Plant Physiology, Head of the Institute of Agricultural Research*, Hindu University, Benares.
17-4-31	N	**Soonawala**, M. F., M.Sc., Maharaja's College, Jaipur (Rajputana).
18-9-35	R	**Srivastava**, Bishwambhar Nath, M.Sc., *Lecturer*, Physics Department, Allahabad University, Allahabad.
19-3-31	†R*	**Srivastava**, P. L., M.A., D. Phil., *Reader*, Mathematics Department, Allahabad University, Allahabad.
10-8-33	R	**Srivastava**, R. C., B.Sc., (Tech.), *Sugar Technologist*, Imperial Council of Agricultural Research, India, Cawnpore.
15-9-31	N	**Shrikantia**, C., B.A., D.Sc., Medical College, Mysore.
19-12-33	R	**Strang**, J. A., M.A., B.Sc., *Professor of Mathematics*, Lucknow University, Badshah Bagh, Lucknow.
24-1-33	N	**Subramanian**, S., M.A., Mathematics Department, Annamalai University, Annamalainagar P. O., South India.
17-4-31	R*	**Sulaiman**, S. M., Hon'ble Sir, *Chief Justice*, High Court, Allahabad.
19-3-31	R	**Taimini**, Iqbal Kishen, Ph. D., Chemistry Department, Allahabad University, Allahabad.
17-12-35	R	**Tandon**, Amar Nath, M. Sc., Physics Department, Allahabad University, Allahabad.
9-11-35	N	**Tandon**, Prem Narain, M.Sc., I.C.S., *Joint Magistrate*, Gaya, (B. and O.)
3-4-33	R	**Thompson**, C. D., M.A., *Professor of Economics*, Allahabad University.
19-3-31	R	**Toshniwal**, G. R., M.Sc., Physics Department, Allahabad University, Allahabad.
3-4-34	R	**Varma**, Rama Shanker, M.Sc., Christ Church College, Cawnpore.
20-12-34	R	**Varma**, S. C., M.Sc., Zoology Department, Allahabad University, Allahabad.
9-2-34	R	**Vaugh**, Mason, B.Sc., (Ing), *Agricultural Engineer*, Allahabad Agricultural Institute, Naini, E. I. Ry. (Allahabad.)
19-3-31	†N*	**Vijayaraghavan**, T., D. Phil., *Reader*, Mathematics Department, Dacca University, Ramna, Dacca.
20-4-35	†N	**Vishwanath**, B., Rai Bahadur, F.I.C., *Imperial Agricultural Chemist*, Imperial Agricultural Research Institute, Pusa, B. and O.
20-4-35	†N	**Wadia**, D. N., M.A., B.Sc., F.G.S., F.R.G.S., Geological Survey of India, 27 Chowringhee, Calcutta.
1-1-30	†R*	**Wali**, Mohammad, Ch., M.A., Ph.D., I.E.S., *Professor of Physics*, Lucknow University, Lucknow.
15-9-31	R	**Wall**, W. G. P., M.Sc., I.E.S., Associate I.E.E., M.R.S.T., *Principal*, Training College, Allahabad.

N.B. The Secretaries will be highly obliged if the members will kindly bring to their notice errors, if there be any, in their titles, degrees, and addresses.

APPENDIX 4

LIST OF EXCHANGE JOURNALS

	Journals	Publishers
1.	The Bell System Technical Journal ...	The American Telephone and Telegraph Coy., New York, (U. S. A.)
2.	Proceedings of the Imperial Academy of Japan.	The Imperial Academy, Ueno Park, Tokyo.
3.	Journal of the Franklin Institute ..	The Franklin Institute of the State of Pennsylvania, Philadelphia, Penna, (U.S.A.)
4.	Bell Telephone System (Technical Publications).	The Bell Laboratories, New York.
5.	Collected Researches of the National Physical Laboratory.	The National Physical Laboratory, Teddington, Middlesex, England.
6.	Report of the National Physical Laboratory.	Ditto.
7.	The Electrician	The Electrician, Bouverie, House, London.
8.	Proceedings of the Cambridge Philosophical Society.	The Philosophical Society, Cambridge.
9.	Proceedings of the Royal Society of Edinburgh.	The Royal Society of Edinburgh, Edinburgh, Scotland.
10.	Journal and Proceedings of the Asiatic Society of Bengal.	The Asiatic Society of Bengal, Calcutta.
11	Indian Journal of Physics ...	The Indian Association for Cultivation of Science, Calcutta.
12.	Scientific Notes of the India Meteorological Department.	The Director-General of Observatories, Poona 5.
13.	Memoirs of the India Meteorological Department.	Ditto.
14.	Journal of the Egyptian Medical Association.	The Egyptian Medical Association, 3 Sharia El-Sanafiri, Abdin, Cairo, Egypt.
15.	Bulletin of the Patna Science College Philosophical Society.	The Patna Science College Philosophical Society, Patna.
16.	Journal of the Indian Institute of Science.	The Indian Institute of Science, Bangalore.
17.	Current Science	The Indian Institute of Science, Bangalore.
18.	Transactions of the Royal Society of Canada.	The Royal Society of Canada, Ottawa.
19.	Publications of the Kapteyn Astronomical Laboratory.	Kapteyn Astronomical Laboratory, Grön-ingen, Holland.

	Journals	Publishers
20.	Publications of the Dominion Astrophysical Observatory.	The Dominion Astrophysical Observatory Victoria, Canada.
21.	Dominion of Canada Natural Research Council.	Ditto.
22.	Proceedings of the Royal Society of Victoria.	The Royal Society of Victoria, Melbourne, Australia.
23.	Journal and Proceedings of the Royal Society of New South Wales.	The Royal Society of New South Wales, Sydney, Australia.
24.	Transactions and Proceedings of the New Zealand Institute.	The New Zealand Institute, Wellington, New Zealand.
25.	Publications of the Alleghany Observatory.	The Alleghany Observatory of the University of Pittsburgh, Alleghany City, (U.S.A.)
26.	Publications of the Observatory of the University of Michigan.	The Observatory Library, University of Michigan, Michigan (U. S. A.)
27.	Lick Observatory Bulletin ...	The Lick Observatory, University of California, Berkeley (U. S. A.)
28.	Proceedings of the American Academy of Arts and Sciences.	The American Academy of Arts and Sciences, Boston (U S A.)
29.	Memoirs of the American Academy of Arts and Sciences.	Ditto.
30.	Journal of Mathematics and Physics.	The Massachusetts Institute of Technology, Cambridge, Mass (U. S. A)
31.	Proceedings of the National Academy of Sciences.	The National Academy of Sciences, Washington (U. S. A)
32.	Transactions of the Royal Society of South Africa.	The Royal Society of South Africa University of Cape-Town Rondebosch, South Africa.
33.	Proceedings of the Academy of Natural Sciences of Philadelphia.	The Academy of Natural Sciences, Philadelphia (U. S. A.)
34.	Sinensia	The Metropolitan Museum of Natural History Academia Sinica, Nanking, China
35.	Proceedings of the American Philosophical Society.	The American Philosophical Society, Philadelphia (U. S. A.)
36.	American Journal of Science ...	The American Journal of Science, New Haven (U. S. A.)
37.	Bureau of Standards, Journal of Research.	The Director, Deptt. of Commerce, Bureau of Standards, Washington (U. S. A)
38.	Contributions from the Mount Wilson Observatory.	The Mount Wilson Observatory, Pasadena, California (U. S. A)
39.	Communications (Solar Observatory)	Ditto.

	Journals	Publishers
40.	Annual Report of the Director of the Mount Wilson Observatory.	The Mount Wilson Observatory, Pasadena, California.
41.	Journal of Chemical Physics ...	The American Institute of Physics, New York, N. Y.
42.	Review of Scientific Instruments ...	Ditto.
43.	Transactions of the Astronomical Observatory of Yale University.	The Astronomical Observatory of Yale University, New Haven (U. S. A.)
44.	Publications in Zoology, University of California.	The University Library, Exchange Deptt, Berkeley California (U. S. A.)
45.	The Philippine Journal of Science ...	The Library, Bureau of Science, Manila, P. I. (U. S. A.)
46	Anzeiger (Mathematics and Science).	Akademie der Wissenschaften, Vienna, Austria.
47.	Almanack	Ditto.
48.	Anzeiger (Philosophy and History).	Ditto.
49.	Bulletin de La Classe Des Sciences.	The Academie Royale de Belgique, Brüssels, Belgium.
50.	Annales De L'Institute Henri Poincare.	The Institute Henri Poincare, Paris (France).
51.	Mathematische Und Naturwissenschaftliche Berichte Ana Ungaru.	The Ungarische Akademie der Wissenschaft, Buda-Pest, Hungary.
52.	Sitzungsberichte Der Preussischen Akademie.	Preussischen Akademie der Wissenschaften, Berlin, Germany.
53.	Berichte Der Deutschen Chemischen Gesellschaft.	Deutsche Chemische Gesellschaft, Berlin, Germany.
54.	Nachrichten Von der Gesellschaft der Wissenschaften Zu Göttingen Mathematisch-Physikalische Klasse. Fachgruppe I. Mathematik.	Gesellschaft der Wissenschaften Zu Göttingen, Göttingen, Germany.
55.	„ II. Physik, Astronomie, Geophysik, Technik.	Ditto.
56.	„ III. Chemie, Einschl. Physikalische Chemie.	Ditto.
57.	„ IV. Geologie und Mineralogie.	Ditto.
58.	„ V. Geographie.	Ditto.
59.	„ VI. Biologie.	Ditto.
60.	Geschaftliche Mitteilungen ..	Ditto.
61.	Sitzungsberichte, Mathematische Naturwissenschaftliche Klasse.	Bibliothekar, Heidelberger Akademie der Wissenschaften, Heidelberg Germany.
62.	Berichte Der Mathematische Physischen Klasse.	Sachsische Akademie der Wissenschaften, Leipzig. C. I.

Journals	Publishers
63. Abhandlungen Der Mathematisch-Physischen Klasse.	Sachsische Akademie der Wissenschaften, Leipzig, C. I.
64. Prävariskische Glieder Der Sächsisch-Fichtelgebirgischen Kristallinen Schiefer.	Ditto.
65 Sitzungsberichte der Mathematisch-Naturwissenschaftlichen.	Bayerische Akademie der Wissenschaften Zu München, München, Germany.
66. Communication from the Physical Laboratory, Leiden.	The Physical Laboratory, Leiden, Holland.
67. Communications from the Kamerlingh Onnes Laboratory.	Ditto.
68. Rendiconti.	Rendiconti Del Circolo Mathematico Di Palermo, Palermo (Italy).
69. National Research Council of Japan, Report.	The National Research Council of Japan, Tokyo, Japan.
70. Japanese Journal of Mathematics ...	Ditto.
71. Japanese Journal of Botany ...	Ditto.
72. Japanese Journal of Physics ...	Ditto.
73. Japanese Journal of Astronomy and Geophysics.	Ditto.
74. Journal of the Faculty of Science, Series I, Mathematics.	The Dean of the Faculty of Science, Hokkaido, Imperial University, Sapporo, Japan.
75. Collected Work from the Faculty of Science.	The Library of the Faculty of Science, Osaka, Imperial University, Osaka, Japan.
76. Proceedings of the Physico-Mathematical Society of Japan.	The Physico-Mathematical Society of Japan, Tokyo, Japan.
77. Scientific Papers of the Institute of Physical and Chemical Research.	Institute of Physical and Chemical Research Komagome, Hongo, Tokyo.
78. Journal of Science of the Hiroshima University (Zoology).	The Hiroshima University, Hiroshima, Japan.
79. The Keijo Journal of Medicine ...	The Medical Faculty, Keijo Imperial University, Chosen, Japan.
80. Bulletin De L'Academie Des Sciences Mathematiques et Naturelles.	The Akademie der Wissenschaft, Leningrad, Soviet-Russia
81. Journal Du Cycle De Physique et De Chemie.	Academie des Sciences D'Ukraine, Kyiv, Ukraine.
82. Journal Du Cycle Mathematique ...	Ditto.
83. Bulletin de La Classe des Sciences Physiques et Mathematiques.	Ditto.
84. Memorias Do Instituto Oswaldo Cruz.	The Instituto Oswaldo Cruz, Brazil (U.S.A.)

Journals.	Publishers.
85. Physikalische Zeitschrift Der Sowjetunion.	Chikovsakaya 16, Kharkov, Soviet-Russia.
86. Geographical and Biological Studies of Anopheles Maculipennis in Sweden	Kungliga Svenska Vetenskapsakademie, Stockholm, Sweden.
87. Kungi Fysiografiska Sällskapets Forhandlingar.	The Universitet, Land, Sweden.
88. Uppsala Universitets Arsskrift ...	Universitet, Uppsala, Sweden.
89. Compte Rendu Des Seances De La Societe De Physique et D'Histoire Naturelle.	Societe D'Historie Naturelle et de Physique, Geneva, Switzerland.
90. Comptes Rendus Mensuels Des Seances De La Classe De Medicine.	Academie Polonaise Des Sciences et Des Lettres, Cracovie, Poland.
91. Comptes Rendus Mensuels Des Seances De La Classe Sciences Mathematiques et Naturelles.	Ditto.
92. Bulletin International De L'Academie Polonaise Des Sciences et Des Lettres Classe Des Sciences Mathematiques et Naturelles, Serie A.	Imprimerie De L'Universite, Cracovie, Poland.
93. Ditto Ditto Serie B. 1.	Ditto.
94. Ditto Ditto Serie B. 2.	Ditto.
95. Bulletin International De L'Academie Polonaise Des Sciences et Des Lettres Classe De Medicine.	Ditto.
96. Acta Physica Polonica,	Ditto.
97. Sprawozdania Z posiedzen Towarzystwa Naukowego Warszawskiego (History Literatury).	Societe des Sciences et des Lettres de Yarsovie, Warsaw, Poland.
98. Ditto (Phisiology)	Ditto.
99. Ditto (Matematyczno-fizycznych)	Ditto.
100. Ditto (Biologicznych) ...	Ditto.
101. Bureau of Fisheries (Document) ...	The Commissioner of Fisheries, Washington (U. S. A.)
102. Science Bulletin	University of Kansas, Lawrence, Kansas (U. S. A.)
103. Mathematisk-Fysiske Meddelelser	Kongelige Danske Videnskabernes Selskab, Copenhagen, Denmark.
104. Biologiske Meddelelser ...	Ditto.

	Journals.	Publishers.
105.	Comptes-Rendus des Travaux Du Laboratoire Carlsberg.	The Carlsberg Laboratorium, Kobenhavn, Valby, Denmark.
106.	Memoirs de L'Academie Royal des Sciences et de Lettres de Denmark.	The L'Academie Royale des Sciences et des lettres de Denmark.
107.	Transactions of the National Institute of Sciences of India.	The Secretary, National Institute of Sciences of India, 1 Park Street, Calcutta.
108.	Proceedings of the National Institute of Sciences of India.	Ditto.
109.	Proceedings of the Indian Academy of Sciences.	The Secretary, Indian Academy of Sciences, P. O. Hebbal, Bangalore.
110.	Transactions of the Bose Research Institute.	The Director, Bose Research Institute, 93 Upper Circular Road, Calcutta.
111.	Electrotechnics	The Secretary, Electrotechnics, Indian Institute of Science, P. O. Hebbal, Bangalore.
112.	Science and Culture	The Secretary, Science and Culture, Dhurumtolla Street, Calcutta.
113.	Indian Physico-Mathematical Journal.	The Editor, Indian Physico-Mathematical Journal, Calcutta.
114	Nagpur University Journal .	The Registrar, Nagpur University.
115.	Scientific Monographs of the Imperial Council of Agricultural Research.	Imperial Council of Agricultural Research, New Delhi/Simla.
116.	Indian Journal of Agricultural Science.	Ditto.
117.	Indian Journal of Veterinary Science and Animal Husbandry.	Ditto.
118.	Travaux De La Station Biologique	Director, De La Station Biologique, Paris, France.
119.	Scientific Papers	National Research Institute of Physics Acadimia Sinica, Shanghai, China.
120.	Helminthological Abstracts ...	Imperial Bureau of Agricultural Parasitology, Herts, England.
121.	Horticultural Abstracts ...	Imperial Bureau of Fruit Production, Kent, England.
122.	Technical Communications ...	Imperial Bureau of Soil Science, Harpenden, England.
123.	Technical Communications and Collected Papers.	Imperial Bureau of Animal Nutriton, Rowett Institute, Scotland.

	Journals.	Publishers.
124.	Bulletins of the Imperial Bureau of Plant Genetics.	Imperial Bureau of Plant Genetics, Aberystwyth, England.
125.	Plant Breeding Abstracts ...	Imperial Bureau of Plant Genetics.
126.	Comptes Rendus (Doklady) ..	De L'Academie Des Sciences De L'URSS, Moscou.
127.	Journal of the Royal Astronomical Society of Canada.	The Royal Astronomical Society of Canada.

APPENDIX 5

JOURNAL SUBSCRIBED BY THE ACADEMY OF SCIENCES U.P., DURING THE YEAR 1935.

PHYSICS

1.	Die Naturwissenschaften, 23 Jahrgang.	Hirschwaldsche Buchhandlung, Berlin, N. W. 7.

APPENDIX 6

LIST OF PAPERS READ BEFORE THE ACADEMY OF SCIENCES, U.P., DURING THE PERIOD APRIL, 1935, TO DECEMBER, 1935

1. Taylor's series and Borel's Polygon of Summability by Mr. S. P. Jain, M.Sc., Allahabad University.
2. On a modified theory of gravitation based on Sulaiman's theory by Mr. Satyendra Ray, M.Sc., Lucknow University.
3. Chemical examination of Glycosmis Pentaphylla and the constitution and synthesis of its active principle by Dr. S. Dutt, D.Sc., Allahabad University.
4. Some aspects of nitrogen fixation in Soil by Dr. N. R. Dhar, D.Sc., F. I. C., I. E. S., and Mr. S. K. Mukerji, M.Sc., Allahabad University.
5. New Hemiurids (Trematoda) from Indian fresh-water fishes. Part II—A rare parasite of the Subfamily Dinurinae Looss, 1907, from clupea ilisha by Mr. Har Dayal Srivastava, M.Sc., Allahabad University.
6. Rare parasites of the family Monorchiidae Odhner, 1911, from an Indian fresh-water fish-Ophiocephalus punctatus by Mr. Har Dayal Srivastava, M.Sc., Allahabad University.
7. On the chemical examination of the bark of Terminalia Arjuna, Bedd. Part I—The isolation of Arjunin, by Mr. Radha Raman Agarwal, M.Sc., and Dr. S. Dutt, D.Sc., Allahabad University.
8. A criticism of the second universal principle of Sulaiman by Mr. Satyendra Ray, M.Sc., Lucknow University.
9. Measurement of ionisation of Kennelly-Heaviside layer at Allahabad by Messrs. G. R. Toshniwal, M.Sc., and B. D. Pant, M.Sc., Allahabad University.
10. Studies on the Genus Lecithodendrium Looss by Mr. B. P. Pande, M.Sc., Allahabad University.
11. Recording the ionospheric echoes at the transmitter by Mr. Ram Ratan Bajpai, M.Sc., Allahabad University.
12. Studies on the family Bucephalidæ (Gasterostomata) Part I—Description of New forms from Indian fresh water fishes by Mr. S. C. Varma, M.Sc., Allahabad University.
13. On the so called three species of Cylindrophis Wagler by Mr. Beni Charan Mahendra, M.Sc., Agra University, Agra.
14. On the Subterranean mass-anomalies in India by Mr. B. L. Gulatee, M. A., Trigonometrical Survey of India, Dehradun.
15. On the application of Heaviside's method to the problem of vibrations of pionoforte String by Dr. R. N. Ghosh, D.Sc., and Mr. L. P. Verma, M.Sc., Allahabad University.

16. New Amphistomatous parasites from an Indian fresh water fish, by Mr. Har Dayal Srivastava, M.Sc., Allahabad University.
17. The absorption spectra of the vapour of the oxides of Copper, iron, nickel and cobalt and the determination of their heats of Sublimation by Mr. Hrishikesha Trivedi, M.Sc., Allahabad University.
18. The absorption Spectra of the vapour of the monosulphides of iron, nickel, cobalt and copper and the determination of their heats of Sublimation by Mr. Hrishikesha Trivedi, M.Sc., Allahabad University.
19. The chemical examination of the fruits of Lagenaria Vulgaris Seringe (bitter variety) Part I—The constituents of the oil from the seeds by Mr. Radha Raman Agarwal, M.Sc., and Dr. Shikhibhusan Dutt, D.Sc., Allahabad University.
20. Colour and constitution of dyestuffs derived from Fluorenone by Mr. Mohit Kumar Mukerji, M.Sc, and Dr. Shikhibhusan Dutt, D.Sc., Allahabad University.
21. New trematodes of the family Lecithodendriidae Odhner, 1911, with a discussion on the classification of the family by Dr. H. R. Mehra, Ph.D., Allahabad University.
22. Preliminary account of new trematodes with Ani by Mr. S. C. Varma, M.Sc., Allahabad University.
23. A note on the colouring matter of the flowers of Lantana Camera, Linn by Mr. Jagraj Behari Lal, M.Sc., Allahabad University.
24. Studies in nitrogen fixation in soil by Dr. N. R Dhar, D.Sc., F. I. C., and Mr. S. K. Mukerji, M.Sc., Allahabad University.
25. The nitrogen Atom and the molecule by Mr. L. S. Mathur, M.Sc., Allahabad University, and Dr. P. K. Sengupta, D.Sc., Raja Ram College, Kolhapur (Bombay).
26. Contributions to the Digenetic Trematoda of the Microcheroptera of northern India, Part III—New Distomes of the genus Mesodendrium Faust, 1919 by Mr. B. P. Pande, M.Sc., Allahabad University.
27. On evidences for a lag effect in Zeuner's data on saturated water vapour in Landolt and Bornstein's tables by Mr. Satyendra Ray, M.Sc., Lucknow University.
28. On evidences of tidal waves in an insulated molten interior as obtained in some recent severe earthquakes by Mr. Satyendra Ray, M.Sc., Lucknow University.
29. On Sir Shah Sulaiman's theory by Mr. D. R. Sharma, M.Sc., Benares Hindu University.
30. The mathematical theory of a New Relativity by the Hon'ble Sir Shah Mohammad Sulaiman, Kt., Chief Justice, High Court, Allahabad.
31. Self acceleration or self retardation? The Kinematics of Sulaiman and the dynamics of Newton by Mr. Satyendra Ray, M.Sc., Lucknow University.

32. Graviton or Star Streaming by Mr. Satyendra Ray, M.Sc., Lucknow University.
33. The Colloidal theory of matter and proportionality to distance law in Astrophysics by Mr. Satyendra Ray, M.Sc., Lucknow University.
34. The Chemical examination of Punarnava or Boerhaavia diffusa linn Part II by Mr. Radha Raman Agarwal, M.Sc., and Dr Sikhibhushan Dutt, D.Sc., Allahabad University.
35. On amphistomes with ventral pouch from India by Mr. B. P. Pande, M.Sc., Allahabad University.
36. The absorption spectrum of hydrogen chloride molecule and its upper unstable state, by Mr. Hrishikesha Trivedi, M.Sc., Allahabad University.
37. New Hemiurids (Trematoda) from Indian marine fishes.—Part I by Mr. Har Dayal Srivastava, M.Sc., Allahabad University.
38. New Allocreadids (Trematoda) from the Indian marine fishes.—Part I by Mr. Har Dayal Srivastava, M.Sc., Allahabad University.
39. On a quantum mechanism in Sulaiman's graviton model by Mr Satyendra Ray, M.Sc., Lucknow University.
40. On two new Xiphidiocercaria from the common fresh water snail Indoplanorbis exustus (Deshayes) of northern India by Mr. A. M. D'Rozario, M.Sc., Allahabad University.
41. Use of molasses in the reclamation of alkali and *usar* lands by Dr N. R. Dhar, D.Sc., and Mr. S. K. Mukerji, M.Sc., Allahabad University.
42. A note on Sir Shah Mohammad Sulaiman's new theory of relativity, by Mr. S. C. Damle, M.Sc., Allahabad University.
43. Influence of temperature on the fixation of nitrogen by Azotobacter by Dr. N. R. Dhar, D.Sc., and Mr. S. P. Tandon, M.Sc., Allahabad University.
44. The genitalia and their role in copulation in *Epilachna indica* with a discussion on the morphology of the genetalia in the family by Mr. S. Pradhan, M.Sc., Lucknow University.
45. The absorption spectrum of hydrogen bromide molecule and its upper unstable state by Mr. Hrishikesha Trivedi, M.Sc., Allahabad University.
46. On two mutually contradictory interpretations of Einstein line element by Sulaiman by Mr. Satyendra Ray, M.Sc., Lucknow University.
47. On some toluen Sulphonyl esters of phenols by Dr. S. M. Sane, Ph.D., and Mr. A. B. Sen, M.Sc., Lucknow University.
48. Variation of Physical properties with change in concentration of iodic acid solution by Mr. M. R. Nayer, B.Sc., Lucknow University.
49. Necessary and sufficient condition for the equality of

$$\frac{d}{dy}\int_a^b f(x,y)dx \quad \text{and} \quad \int_a^b \left[\frac{d}{dy} \left\{ f(x,y) \right\} \right] dx$$

by Mr. Uma Kant Shukla, M.Sc., Lucknow University.

50. On the relationship between the soluble fatty acids and the potash equivalent of acids giving barium salts by Dr. B. M. Gupta, Ph.D., Deputy Public analyst to Government of U. P., Lucknow.

51. Influence of lyophillic colloids on the wettability of Naphathalin by Dr. A. C. Chatterji, D.Sc., Dr. Ing., Lucknow University.

52. A note on general line element by Mr. V. V. Narlikar, M.A., and Mr. D. N. Moghe, M.Sc., Benares Hindu University.

53. The field of a nonstatic spherical condensation by Messrs D. N. Moghe, M.Sc., and R. V. Sastry, M.Sc., Benares Hindu University.

54. The first Universal principle of Sulaiman, by Mr. Satyendra Ray, M.Sc., Lucknow University.

55. On the convergence and the summability of the conjugate series of the derived Fourier series, by Mr. K. L. Gupta, M.Sc., Allahabad University.

56. Hydrogen ion concentration and titrable acidity at different stages of fruit ripening, by Mr N. L. Pal, M.Sc., Allahabad University.

57. The quantum statistics and internal constitution of planets, by Dr. D. S. Kothari, Ph.D., Delhi University, and Dr. R. C. Majumdar, Ph.D., Punjab University.

58. A critical review of the current theories of the active nitrogen phenomenon, by Dr. M. N. Saha, D.Sc., F.R.S., and Mr. L. S. Mathur, M.Sc., Allahabad University.

59. The study of the absorption spectra of lead fluoride, by Mr. M. S. Desai, M.Sc., M.T.B. College, Surat.

60. Utilization of waste vegetation I. Gasification of Prickly pear (Opuntia Dillinii), by Dr. B. S. Srikantan, D.Sc., Andhra University and S Rangachari, M.Sc., Engineering College, Madras.

61. On Sulaiman's Single Journey method, by Mr. Satyendra Ray, M.Sc., Lucknow University.

APPENDIX 7

Financial Statement from 1st April, 1935 to 31st March, 1936.

Receipts.

	Rs.	a.	p.	Rs.	a.	p.
Bank Balance on 1st April, 1935				1,866	5	9
U. P. Government Grant				2,000	0	0
Allahabad University Grant				500	0	0
Agra University Grant				250	0	0
Nagpur University Grant				100	0	0
Donations				350	0	0
Membership Fee:—						
Resident fee for 1932	30	0	0			
Resident fee for 1933	15	0	0			
Resident fee for 1934	135	0	0			
Resident fee for 1935	570	0	0			
Resident fee for 1936	291	0	0			
Non-resident fee for 1933	10	0	0			
Non-resident fee for 1934	40	0	0			
Non-resident fee for 1935	130	0	0			
Non-resident fee for 1936	20	0	0			
				1,241	0	0
Compounding subscription				96	0	0
Associate				30	0	0
Sale of Proceedings of the Academy				33	0	0
Bank commission on outside cheques				0	12	0
Total Rs. ...				6,467	1	9

Expenditure.

				Rs.	a.	p.
Establishment				1,204	0	0
Honorarium to Asst. Editor				100	0	0
Contingency. (Including printing, postage stamps and Stationery etc.)				688	11	0
Printing of Proceedings of the Academy of Sciences, U. P.				2,577	10	0
Binding of Journals				40	0	0
Bank charges on outside cheques				9	2	0
Fixed Deposit Account				1,466	0	0
Cash in hand	Rs. 72	0	0			
Bank Balance	„ 309	10	0	381	10	9
Total Rs. ..				6,467	1	9

H. R. MEHRA, PH. D.

Hony. Treasurer,

The Academy of Sciences, U. P.